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BIOLOGICAL SURVEYS OF INSHORE SOFT-BOTTOM COMMUNITIES IN TASMANIA

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Biological Surveys Of Inshore Soft-Bottom Communities In Tasmania

CHAPTER 1

Abstract

Benthic invertebrates were sampled from seagrass, sand and mud habitats around Tasmania from three coastal environment types, Georges Bay, Norfolk Bay and the Tamar River. Seasonal sampling was undertaken at a selected number of sites in each area and a snapshot survey conducted to examine invertebrate assemblages over a broader geographical range.

The habitat study revealed no large differences in densities or diversities between environment types. Vegetated sites generally had highest densities and diversity, although not at all sites in all areas. Hence, in order to maximise invertebrate abundance and diversity both vegetated and shallow and deep unvegetated habitats should be included within a marine reserve system. A distinct assemblage occurred at sandy beach sites, while the remaining sites showed a gradation of assemblage change from deep unvegetated to shallow vegetated with assemblages showing little habitat specificity.

No consistent seasonal trend was apparent in invertebrate densities or diversity. Autumn assemblages were markedly different at four out of nine sites indicating that autumn is the least appropriate season to undertake soft-bottom invertebrate surveys. However, it is not known if the temporal shifts in relationships are truly seasonal or resulted from variability between different sets of samples. In general, the snapshot survey revealed no trend in densities or diversity with regard to geographic location with highest densities and diversity at the most marine dominated vegetated sites. Species assemblages showed little similarity by habitat, or between both near and geographically separated sites. Hence, the habitat and snapshot survey indicate that to cover the range of inshore soft-bottom assemblages, marine reserves should encompass sandy beach habitats, and mud and seagrass habitats covering a broad range of environmental conditions.

Introduction

Tasmanian inshore marine environments can be broadly classified as beaches, embayments or estuaries. These environments contain extensive areas of soft-bottom habitat which can be broadly subdivided into seagrass, sand and mud. While the non-vegetated soft-bottom habitats are the dominant feature of coastal areas around Tasmania, extensive areas of seagrass also occur, with *Posidonia australis* and *Amphibolis antarctica* dominant along the north coast, and *Heterozostera tasmanica* and *Halophila australis* common in estuaries and embayments around the state (Rees 1993). While such habitats are a dominant feature of coastal areas around Tasmania very little work has been done to describe and classify their faunal assemblages and as a result the relationship between habitat types are poorly understood.

Recent work suggests up to 500 km^2 of seagrass beds occurs around the state (Rees 1993), although this appears to be a significant underestimate (Jordan unpubl. data). Despite its present distribution, significant loss of seagrass beds has occurred around Tasmania, mainly in areas with high human activity (Rees 1993). Increased nutrient levels and turbidity (from urban and industrial discharges, catchment usage) appear to play a prominent role in the decline of seagrass habitats. These human induced changes also impact on other surrounding non-vegetated soft-bottom habitats through algal and dinoflagellate blooms and accumulation of wood pulp effluent. Additionally, indirect effects, such as the introduction of exotic species, particularly the northern Pacific seastar, *Asterias amurensis*, have the potential to significantly alter the structure of the invertebrate communities (Davenport and McLoughlin 1993), and therefore impact on the productivity and biodiversity within these areas.

At present the four Tasmanian marine reserves (Maria Island, Tinderbox, Ninepin Point and Governor Island) are dominated by rocky reef communities with only small beds of *Heterozostera tasmanica* represented in the Maria Island reserve. Additionally, very little soft-bottom unvegetated habitats are represented in Tasmanian marine reserves.

Due to the importance of these inshore habitats, and the need to maintain biodiversity, there is a need to adequately represent soft-bottom habitats and their faunal assemblages within a marine reserve system.

We describe here the benthic faunal assemblages in selected soft-bottom habitats around the Tasmanian coast and discuss how the patterns of assemblages in such habitats across a range of coastal environment types may be used to identify representative habitats suitable for inclusion into a marine reserve system. In order to assess the extent of variability in soft-bottom invertebrate assemblages spatial, temporal and habitat variability is addressed.

The aims of the project are:

- To determine the abundance and distribution of biota associated with selected inshore soft-bottom habitats around Tasmania.
- To determine the community structure of inshore soft-bottom habitats and examine the associations between habitats and biotic assemblages.
- To categorise the habitat types in these areas.

Sampling areas were chosen to reflect a range of coastal environments around Tasmania. Norfolk Bay in the south-east is an open embayment consisting of deep mud habitats, a range of semi-exposed and sheltered beaches and shallow seagrass beds dominated by *Heterozostera tasmanica* with smaller amounts of *Halophila australis*. Georges Bay is a large open coastal lagoon containing deep mud habitats and shallow banks consisting of *Heterozostera tasmanica* beds and sand and mud habitats. The Tamar River is a large estuary containing a variety of soft-bottom habitat types ranging from exposed and semi-exposed beaches and *Posidonia australis* beds at the mouth of the estuary to *Heterozostera tasmanica* beds and mud habitats further up the estuary.

There are three components to the study. The first is designed to provide information on the extent that environmental and habitat variation has on invertebrate abundances, diversity and species assemblage (Chapter 2). Three coastal environments, Norfolk Bay (marine embayment), Tamar River (estuary) and Georges Bay (coastal lagoon) were sampled in autumn 1995. Sampling sites in each area were chosen to represent deep (7-15 m) and shallow (0-7 m) strata and cover a range of soft-bottom habitat types (seagrass, mud, sand and sandy-mud).

The second part of the study is designed to provide information on temporal variation of invertebrate abundances and assemblage types (Chapter 3). Samples were taken seasonally from two representative sites in Norfolk Bay, three in Georges Bay and four in the Tamar River.

The third part of the study is designed to provide some appreciation of the geographical variation of soft-bottom benthic assemblages throughout Tasmania (Chapter 4). Twenty-two sites, some of which were also sampled in the habitat component of the study were sampled in winter 1995.

Methods

Field and laboratory methods

Benthic invertebrate samples were collected by diver operated corers (150 mm diameter). In the field cores were bulk fixed in sea water formalin. After allowing at least 24 hours for the specimens to be fixed the samples were sieved through 1 mm mesh then stored in a 70% alcohol, 5% glycerol, 25% water solution. Later the samples were sieved again and the macrofauna sorted from the material retained. Animals collected from this were then identified to easily distinguished taxa and numbers of each taxa recorded.

Identifying the invertebrate macrofauna into convenient taxa means they are grouped on gross morphological characteristics. Frequently these are the features used for feeding and place the animals into different trophic guilds. Consequently, this level of taxonomic identification is unlikely to separate parallel communities that may occur in different biogeographical regions. A detailed study with an objective of selecting areas for the maintenance of species diversity would need to direct more time into taxonomic identification to species level.

Habitat type was broadly defined by the dominant seagrass species in vegetated sites (*Heterozostera*, *Posidonia* and *Ruppia*) and a visual characterisation of sediment type in unvegetated sites (sand, mud and sandy-mud). Due to the large number of core samples generated, the time taken for detailed sieving of seagrass samples, particularly those of *Posidonia*, and the need for accurate taxonomic identifications, insufficient time was available for determination of seagrass biomass per core or sediment grain size analysis. It was considered more important to process a larger number of core replicates for greater statistical power than to attempt to determine what abiotic and other biotic variables are actually responsible for structuring the assemblages. Likewise, macrofauna from beam trawl samples have been sorted to phylum level by site but insufficient time precluded lower level taxonomic identification and were excluded from this analysis. Due to the highly selective nature of the beam trawl for sampling epibenthic fauna it would only provide presence/absence data.

Statistical methods

Multivariate analysis techniques are considered to be conceptually more appropriate than univariate analysis for use in community studies because they compare not only the numbers of species and their relative densities, but also the kinds of species and in most cases the absolute density present (Pontasch & Brusven 1987; Hodda & Nicholas 1986). They are also well suited to soft-sediment communities with usually contain a large species set with a sparse highly skewed abundance arising from distinct clumping in species distributions (Clarke 1993). Univariate analysis (ANOVA) was not applied to the data as it was considered more meaningful to examine similarities in faunal assemblages using multivariate analysis as at times assemblage patterns are not detected in univariate tests of abundance or diversity (Clarke 1993). However, trends in invertebrate abundance, number of taxa and species richness are examined in each component of the study.

For community ecology studies two multivariate analysis methods, cluster analysis and ordination, are recommended (Bayne *et al.* 1988). Cluster analysis sorts data into groups characterised by similar descriptors (taxa for site classification, samples for species classification). Ordination provides a graphic display of the relationships within these groups. Ordination has been conducted using nonmetric multidimensional scaling (MDS). A stress value is given which gives the "goodness of fit" for the ordination to the plotted data. Stress values approaching 0.20 are considered a bad fit and caution is required in interpreting these results, although stress tends to increase with increasing sample size (Clarke 1993).

Multidimensional scaling (MDS) was used to graphically display similarities and differences between faunal assemblages from different sites and cores. Analysis were performed using the MDS package in the Plymouth Routines in Multivariate Ecological Research (PRIMER). Unless otherwise stated a double square root data transformation was used before analysing the data. The Bray-Curtis similarity measure was used with group average clustering. PRIMER uses a non-metric multi-dimensional scaling ordination algorithm.

Multivariate analysis of cores allows comparison of within and between sample variability. It is therefore useful when assessing patterns. However, where there are a large number of cores, reducing the data points to site/time averages makes it easier to see patterns compared with results from replicated cores (Austen 1989). Consequently where a large number of cores existed in the data set data reduction has been undertaken by averaging the replicate cores.

Where results from MDS analysis were indistinct, the significance of differences between samples was tested by the 'analysis of similarities' (ANOSIM) programme in PRIMER which performs a randomisation test on the data and is a distribution free analogue of one-way ANOVA. Both MDS and ANOSIM are described in Clarke & Green (1988) and Clarke (1993).

CHAPTER 2 - HABITAT STUDY

Methods

Benthic core samples were collected during autumn 1995 from eight sites in both Norfolk Bay (Fig. 1) and Georges Bay (Fig. 2) and six sites in the Tamar River (Fig. 3). Three main habitat types (seagrass, sand and mud) and two depth strata (0-7m, 7-15m) were sampled from each environment type, except in the Tamar River where no deep strata were sampled. Full details of habitat type per site, site depth and date sampled is provided in Table 1. The aim of this component of the study was to firstly describe variations in invertebrate abundance, diversity and species assemblages across a range of habitat types and secondly to compare similar habitats between environments.

Results

Physical data

Details of surface temperature and salinity for all sites is presented in Table 2. Temperature varied little between sites and areas with warmest temperatures in Georges Bay. Surface salinity showed more variation reflecting the level of marine or estuarine dominance in areas and sites. Norfolk Bay, an open marine embayment showed the least variation while in the Tamar River salinities were slightly lower and varied by up to 2.4 ppt between sites.

Numbers of individuals and taxa

The distribution and percentage abundance of taxa by area and habitat is presented in Table 3. In all areas and most habitats annelids were the dominant taxa, followed by arthropods and molluscs. The only exception was the high percentage of pharonids at the sand habitat in Norfolk Bay. The greatest similarity in habitats between areas occurred at the *Heterozostera* sites.

Numbers of individuals per site for each area are presented in Fig. 4. Georges Bay sites had median densities around 50 individuals, although sites 2 and 3 showed considerably higher densities. Median densities varied little in Norfolk Bay ranging from 160 to 30 individuals per core. Median densities in the Tamar River sites were generally lower than other areas and similar at most sites, apart from site 1 which had densities higher than any site in Norfolk Bay.

Generally, numbers of individuals were higher and less variable at Norfolk Bay sites than Georges Bay or the Tamar Estuary (Fig. 4). However there were sites where they overlapped and Georges Bay sites 2 and 3 and Tamar site 1 both had median densities that were greater than the highest median density recorded from Norfolk Bay.

In each area highest densities generally occurred at sites vegetated by *Heterozostera*, although this was less apparent in Norfolk Bay. Deep sites were only available for sampling in Georges Bay and Norfolk Bay. These were all unvegetated mud sites and similar sediment types were not present in shallow strata. The Georges Bay deep sites (4,7,8) possessed densities similar to the shallow unvegetated sites (1,5). Two of the Norfolk Bay deep sites (8,9) had densities lower than the shallow unvegetated site 6, however the third site (10) had densities comparable to both shallow vegetated and unvegetated sites.

Number of taxa per area and site showed similar ranges and trends in all three areas with higher numbers of taxa in vegetated than unvegetated habitats (Fig. 5). Georges Bay sites showed considerable variability in the number of taxa per core although the vegetated sites 2 and 3 were generally higher than those from unvegetated sites. There was little difference in the numbers of taxa per core for unvegetated deep (4,7,8) and shallow sites (1,5). Norfolk

Bay showed similar trends with vegetated sites (1,3,5,7) having higher numbers of taxa per core than unvegetated sites (6,8,9,10). All deep mud sites (8,9,10) had similar numbers of taxa. Tamar River vegetated sites (1,4,5) had considerably higher numbers of taxa per core than the vegetated site 3 or the unvegetated sites 2 and 6.

Richness indices per area and site showed similar trends to the number of taxa although the difference between vegetated and unvegetated sites became less pronounced (Fig. 6). High richness indices were found for Georges Bay site 2, Norfolk Bay sites 5 and 7 and the Tamar River sites 4 and 5, all vegetated sites representing the most marine dominated sites in each area. Other vegetated sites, and both shallow and deep unvegetated sites varied little in richness.

Multivariate analysis of individual environments

Norfolk Bay

Three groupings were recognised in the Norfolk Bay ordination (Fig. 7).

1) An assemblage characterised by high densities of Phoronida I, Platyischnopidae, Haustonidae, and Opheliidae and low density of Capitellidae. This assemblage only occurred at site 6 a high energy, unvegetated sandy beach site and showed the least similarity to the other sites.

2) An assemblage characterised by high densities of oligochaetes, Nereididae, *Leptochella dubia*, Capitellidae, *Paradexumine churinga*, and Phoxocephalidae, and low density of Phoronida I. This assemblage occurred at sites 1, 3, 5 and 7, all *Heterozostera* sites.

Within this grouping there were differences between the site 1, 3, and 7 assemblages, while site 5 replicates were very diverse. The differences between site 1 and 7 replicates were not statistically significant (ANOSIM, $p > 0.05$). Differences between replicates from sites 1 and 3 and 7 and 3 were significantly different (ANOSIM, $p < 0.05$). Compared to sites 1 and 7, site 3 had higher densities of *Theora fragilis* and *Callianassa* and lower densities of *Leptochelia dubia*, Eunicidae II Syllidae, *Paradexumine churinga*, *Apseudes* II, Opheliidae and *Corophium* I.

3) An assemblage characterised by high densities of *Nephtys* sp, *Theora fragilis*, *Lumbrinereis* spp and low densities of Phoronida I, Nereididae, Oligochaetes, and Opheliidae. This assemblage occurred at sites 8, 9 and 10. These sites were deep unvegetated sites.

Two assemblages can be identified from this grouping. Although one site 9 sample grouped with site 10 (Fig. 7) there is a significant difference between the site 8 and 9, and site 10 samples (ANOSIM, $p < 0.01$). The differences at site 10 were caused by the high density of *Lumbrinereis*, Capitellidae, Nereididae and Caprellidae I and low densities of *Thora fragilis*, *Callianassa*, and *Echinocardium cordatum*.

Tamar Estuary

Unlike the Norfolk Bay and Georges Bay ordination there are no obvious groupings in the Tamar ordination (Fig. 8). This is because of the diverse range of habitats that were sampled in this area so that each site tends to separate out. The only two sites where there was no statistically significant separation were sites 1 and 3. Only three replicates were collected from each of these sites and it is probably due to the reduced statistical power that differences between these sites were not significant. Although in the ordination site 4 and 5 replicates overlapped these were found to be significantly different (ANOSIM, $p < 0.05$) reflecting the high between replicate variability.

In view of the results of the analysis of the combined data (Fig. 10), four assemblages are recognised in the Tamar data.

1) An assemblage characterised by high densities of Haustonidae, *Cirolana* II, Anthuridae VII and Bivalve XXIII, and low densities of many species. This assemblage only occurred at site 6 a high energy, unvegetated sandy beach site.

2) An assemblage characterised by high densities of Capitellidae, Orbinidae, *Callianassa* spp, *Nephtys* spp and Amphipod CXVIII and low densities of many species. This assemblage occurred at the unvegetated site 2 and *Heterozostera* site 3, both shallow sites with similar sandy mud sediments.

3) An assemblage characterised by high densities of Spionids, Nereididae, Cirratulidae, Syllidae, Terebellidae and Hesionidae. This assemblage only occurred a site 1 a shallow *Heterozostera* site.

4) An assemblage characterised by high densities of *Parawaldeckia* I, ophiuroids, *Pasianothrochus irisondontes*, and *Ampelisciphotis* sp and low densities of Spionidae and Syllidae. This assemblage was found at sites 4 and 5, *Posidonia* sites at the mouth of the river.

Georges Bay

Four groupings are recognised in the Georges Bay ordination (Fig. 9).

1) An assemblage characterised by high densities of Nereididae, Bivalve 1 and Platyischnopidae and low density of Spionidae, Capitellidae, *Nephtys* sp, Maldanidae and *Theora fragilis*. This assemblage only occurred at site 1 a high energy, unvegetated sandy beach site.

2) An assemblage characterised by high densities of oligochaetes, Capitellidae, Spionidae, Gastropod XXXIII, Bivalve VIII and *Paradexamina churinga* and low densities of *Nephtys* sp and *Theora fragilis*. This assemblage occurred at the *Heterozostera* sites 2 and 3.

Within this grouping significant differences were detected between sites 2 and 3 (ANOSIM, $p < 0.5$). The analysis of univariate data revealed that species richness was a lot higher at site 2 than 3 (Fig. 6), consequently there were numerous taxa present at site 2 but not site 3. However there was one taxa, Anthozoa VIII that was highly abundant at site 3 but absent from site 2.

3) An assemblage characterised by high densities of *Theora fragilis*, *Macttra pura* and Phoxocephalidae and low densities of Nemertean II, Spionidae, Capitellidae and Maldanidae. This assemblage only occurred at site 5 a shallow, unvegetated mud site.

4) An assemblage characterised by high densities of Nemertean II, *Nephtys* sp, Maldanidae, *Theora fragilis*, Ostracod VIII and low densities of Oligochaetes, Nereididae, Spionidae, and Capitellidae. This assemblage occurred at sites 4, 6, 7 and 8 which were similar in that they possessed soft mud sediments. However sites 4, 7 and 8 were deep unvegetated sites while site 6 was a shallow *Heterozostera* site.

Within this group site 6 was significantly different from sites 4 and 8 (ANOSIM, $p < 0.05$). These differences were because of higher densities at site 6 of Terebellidae, Capitellidae, Flabelligeridae II, and Maldanidae and lower densities of Ostracod VIII and Nemertean II than those at sites 4 and 8.

Multivariate analysis of combined data

Assemblages from all three habitat types in all three areas were compared using multivariate analysis (Fig. 10). To reduce the complexity of this analysis, data have been reduced by averaging the number of individuals for taxa collected in the replicates for each site.

When all sites across all areas are combined, in all cases but one, neither sites with the same habitat type, nor sites within the same area, grouped together. The three unvegetated sandy beach sites, Norfolk Bay site 6, Georges Bay site 1 and Tamar site 6 possessed assemblages more similar to each other than to the other sites. Levels of similarity for these three sites to the other sites were comparable, regardless as to whether the other sites were vegetated or unvegetated.

The other sites were distributed with shallow, vegetated marine sites at one end, and deep, unvegetated mud sites at the other. Within this group there were some shallow vegetated sites (eg. Georges Bay site 6 and Tamar site 3) that were more similar to unvegetated sites than other vegetated sites, while Norfolk Bay site 10, a deep unvegetated site was more similar to some of the shallow vegetated sites than the other unvegetated sites.

Discussion

Numbers of individuals and taxa

Variations in the numbers of individuals and number of taxa were as high between sites within each area as they were between areas. The large ranges apparent at each site reflect the considerable patchiness in the distribution of the fauna within these habitats. Such levels of patchiness have been commonly found in benthic invertebrate assemblages, particularly those in seagrass habitats (Collet *et al.* 1984; Wells *et al.* 1985; Hutchings *et al.* 1991). Differences in environmental conditions (eg. salinity, temperature) are apparent both between sites in an area and between areas. Between site differences in numbers of individuals were greatest in Georges Bay and smallest in Norfolk Bay. The fact that Norfolk Bay showed generally higher numbers of individuals and the least between site variability may be related to the small range of salinity and temperature compared to Georges Bay and the Tamar River. The results do not show any clear cut inherent differences between the numbers of taxa in the three environmental types sampled. Therefore, if the intention of declaring a marine reserve was the preservation of maximum number of individuals or number of taxa there is no advantage in concentrating on one of these environmental types.

In both Georges Bay and the Tamar River numbers of individuals per core were generally higher in vegetated than unvegetated sites, a pattern that was not as apparent in Norfolk Bay. Highest species richness were found in the marine dominated vegetated sites in all three areas, however not all vegetated sites showed higher richness than unvegetated sites.

It is generally regarded that seagrass beds have higher abundance and diversity of invertebrates that unvegetated areas (Kikuchi and Peres 1977; Lewis 1984; Peterson and Black 1986; Hutchings *et al.* 1991; Edgar 1990; Orth 1992; Edgar *et al.* 1994). While this was true for many sites in this study, several unvegetated sites showed similar densities and richness than vegetated sites in the same area, particularly in Norfolk Bay. Consequently, in order to maximise invertebrate diversity within a marine reserve system both vegetated and unvegetated habitats should be included incorporating both shallow and deep strata.

Multivariate analysis of individual environments

The multivariate analysis of sites within each area revealed some similarities in the structuring of invertebrate assemblages in these soft-bottom habitats. In all areas a distinct assemblage was present at the sandy beach sites. However, the Tamar results illustrates the major problem in trying to interpret how different groupings have to be before they represent

different assemblages. No obvious groupings were present in the Tamar sites, most likely reflecting the large range of habitat types sampled and physical parameters present between sites. The Norfolk Bay and Georges Bay ordinations provided groupings of samples that were easily separated and could in most cases be linked to different habitat types. However, these habitat groupings showed considerable variability and at times were defined as significantly different assemblages. Hence, the data suggests that physical factors such as sediment type are at times important determinants of faunal composition as vegetated and unvegetated sites with similar sediment types at times grouped together.

Multivariate analysis of combined data

The present results suggest a distinct assemblage occurs in shallow sandy beach sites. However, due to the low number of shallow sandy beach sites in this study caution is required in making such a conclusion because a wider range of sites may have revealed a number of intermediate assemblages. In Shark Bay (WA) a similar trend was found with little overlap in the faunal species composition of seagrass beds and nearby sand areas (Wells *et al.* 1985). A gradation of assemblage change is apparent for all other sites from deep unvegetated to shallow vegetated, although some deep unvegetated sites were more similar to vegetated sites than the other unvegetated sites

The results suggest that the environmental conditions at each site are more important in determining the invertebrate assemblage than regional or specific habitat conditions. Several studies have found that most invertebrate species show little habitat specificity (Hutchings *et al.* 1991; Edgar 1990). In both these studies faunal similarities were greater between different seagrass species at the same site than those found in the same seagrass species at different sites. Collett *et al.* (1984) found that the principal determinant of the invertebrate species composition at *Posidonia* sites was not latitude but sediment and salinity characteristics. The implication of this is that in Tasmania in order to cover the full range of inshore soft-bottom invertebrate assemblages marine reserves should encompass sandy beach habitats, and mud and seagrass habitats covering a broad range of environmental conditions.

However, it must be emphasised that not all substrate types, a limited salinity range, and not all seagrass species found in Tasmanian inshore soft-bottom habitats were sampled in this study. Extensive areas of *Amphibolis antarctica* are found along the north coast of Tasmania and deep beds (up to 22 m) of *Posidonia* are present around Flinders Island. Also, at least in south eastern Tasmania, sites 10 to 20m deep with substrates of sand and shell debree are common.

Caution is also required with the interpretation of this data as it is a single time assessment of species assemblages with temporal changes in the assemblages not taken into account. The following chapter seeks to address the significance of such temporal variability.

Table 1. Details of sites sampled for the habitat component of the study.

AREA	SITE NO. - NAME	HABITAT SAMPLE DATE	DEPTH RANGE	HABITAT TYPE
Norfolk Bay	1 - Sommer Bay	13/5/95	3-4m	*Heterozostera*
	3 - Prices Bay	13/4/95	2-4m	*Heterozostera*
	5 - Lime Bay - veg.	13/4/95	3-4m	*Heterozostera*
	6 - Lime Bay - unveg.	22/5/95	1-3m	sand
	7 - Smooth Island	13/4/95	3-4m	*Heterozostera/Halophila*
	8 - Flinders Point	11/5/95	10-12m	mud
	9 - Deer Point	11/5/95	10-12m	mud
	10 - Chronicle Point	11/5/95	10-12m	mud
Georges Bay	1 - Entrance Channel	31/5/95	4-5m	sand
	2 - Entrance Bank	31/5/95	1-2m	*Heterozostera*
	3 - Steiglitz Beach	1/6/95	3-4m	*Heterozostera*
	4 - Mc Donalds Point	29/5/95	8-10m	mud
	5 - Moulting Bay	29/5/95	3-4m	sandy mud
	6 - Outer Moulting Bay	30/5/95	2-3m	*Heterozostera*
	7 - Steiglitz Beach deep	30/5/95	9-10m	mud
	8 - Beauty Bay deep	30/5/95	10-11m	mud
Tamar River	1 - Sandy Beach	4/5/95	2-4m	*Heterozostera/Halophila*
	2 - West Arm	4/5/95	2-4m	sandy mud
	3 - Kelso	4/5/95	2-4m	*Heterozostera*
	4 - Lagoon Bay	4/5/95	2-4m	*Posidonia*
	5 - North West Bank	4/5/95	2-4m	*Posidonia*
	6 - Greens Beach	4/5/95	2-4m	sand

Table 2. Temperature and salinity characteristics for sites sampled in the habitat study.

AREA	SITE NO. - NAME	SURFACE TEMP ^0C	SURFACE SALINITY ppt
Norfolk Bay	1 - Sommer Bay	12.6	34.4
	3 - Prices Bay	13.4	34.3
	5 - Lime Bay - veg.	13.1	34.5
	6 - Lime Bay - unveg.	13.2	34.6
	7 - Smooth Island	13.3	34.5
	8 - Flinders Point	13.5	34.3
	9 - Deer Point	13.5	34.2
	10 - Chronicle Point	13.5	34.3
Georges Bay	1 - Entrance Channel	14.4	33.2
	2 - Entrance Bank	14.4	33.2
	3 - Steiglitz Beach	14.0	31.9
	4 - McDonalds Point	14.5	31.4
	5 - Moulting Bay	14.5	32.2
	6 - Outer Moulting Bay	14.0	32.5
	7 - Steiglitz Beach deep	14.3	31.9
	8 - Beauty Bay deep	14.0	31.4
Tamar River	1 - Sandy Beach	13.4	31.6
	2 - West Arm	13.4	31.8
	3 - Kelso	13.5	32.8
	4 - Lagoon Bay	14.3	33.5
	5 - North West Bank	14.3	33.5
	6 - Greens Beach	13.4	34.0

Table 3. Percentage of total individuals in each habitat type of the major taxa in each of the three areas sampled.

	GEORGES BAY				NORFOLK BAY			TAMAR RIVER			
	Het	Sand	Mud	Sandy mud	*Het*	Sand	Mud	*Het*	*Pos*	Sand	Sandy mud
Annelids	74.4	37.5	55.4	15.6	55.1	5.6	70.3	85.3	23.7	8.5	43.5
Echinoderms	0.2	-	3.3	0.6	0.4	-	2.2	2.0	10.7	3.3	-
Arthropods	8.1	26.5	12.1	16.2	39.1	13.7	5.7	8.8	47.1	72.9	49.6
Molluscs	11.1	32.8	20.3	65.6	3.3	1.0	11.3	2.4	17.5	11.0	3.5
Pharonids	-	-	-	-	-	78.6	1.2	-	-	-	-
Cnidarians	4.4	-	0.3	1.2	-	-	-	-	-	-	2.6
Nemertina	1.7	3.1	7.5	0.6	1.9	1.0	8.3	1.3	-	1.3	-
Others	0.1	0.1	1.1	0.2	0.2	0.1	1.0	0.2	1.0	3.0	0.8

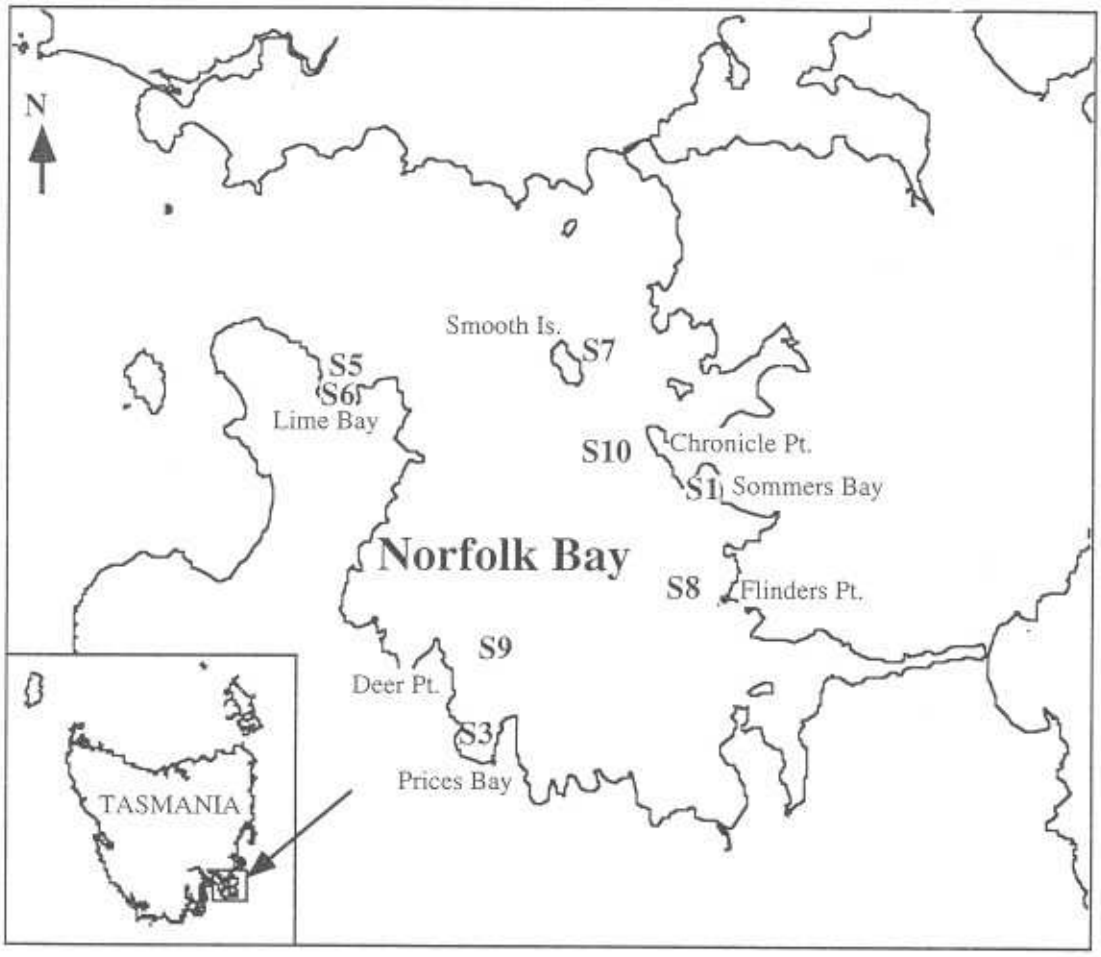


Fig. 1. Map showing distribution of sampling sites in Norfolk Bay, south-east Tasmania

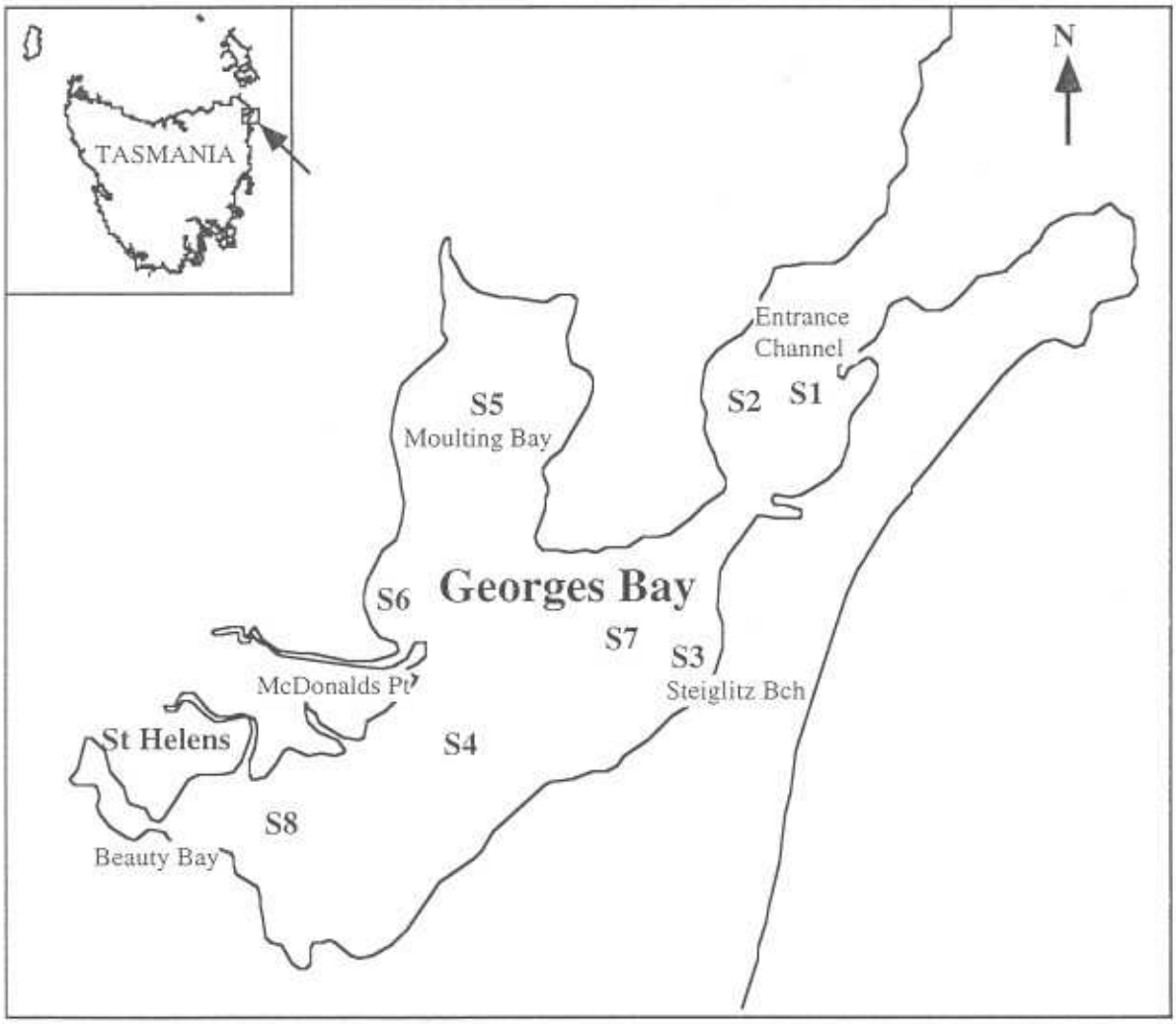


Fig. 2. Map showing distribution of sampling sites in Georges Bay, north-east Tasmania

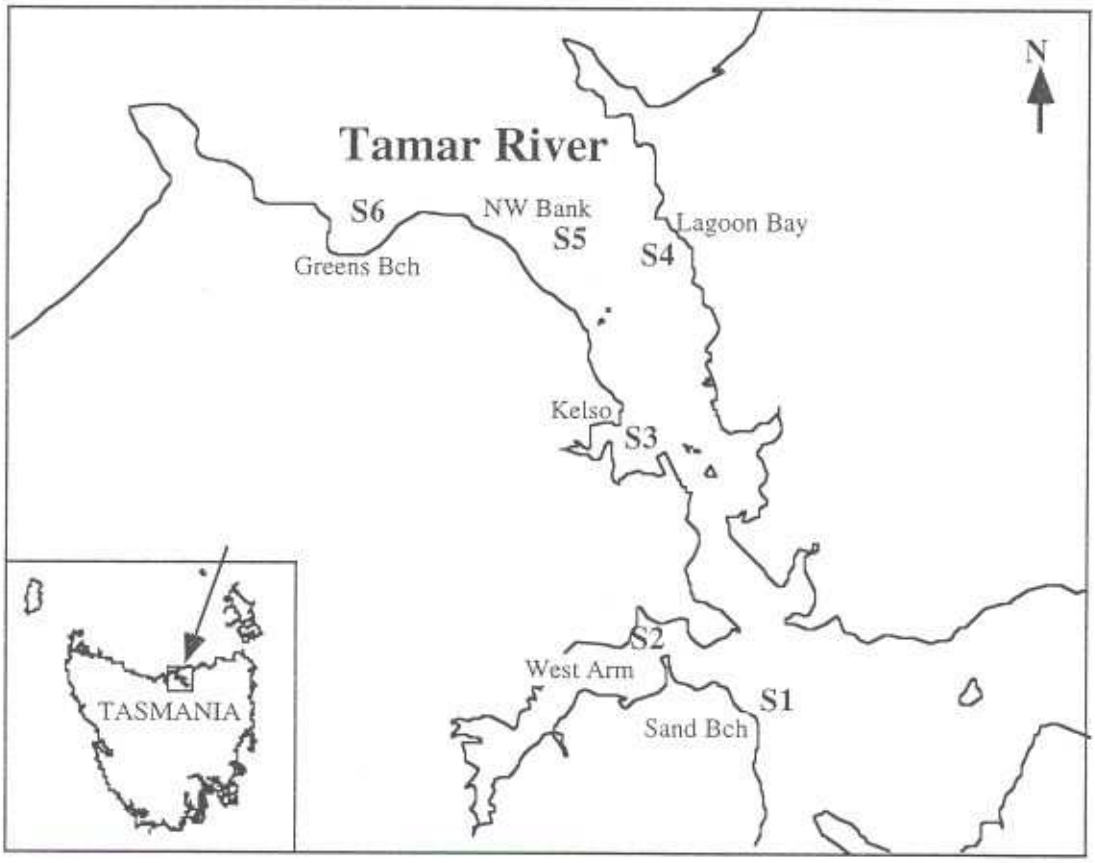


Fig. 3. Map showing distribution of sampling sites in Tamar River, northern Tasmania

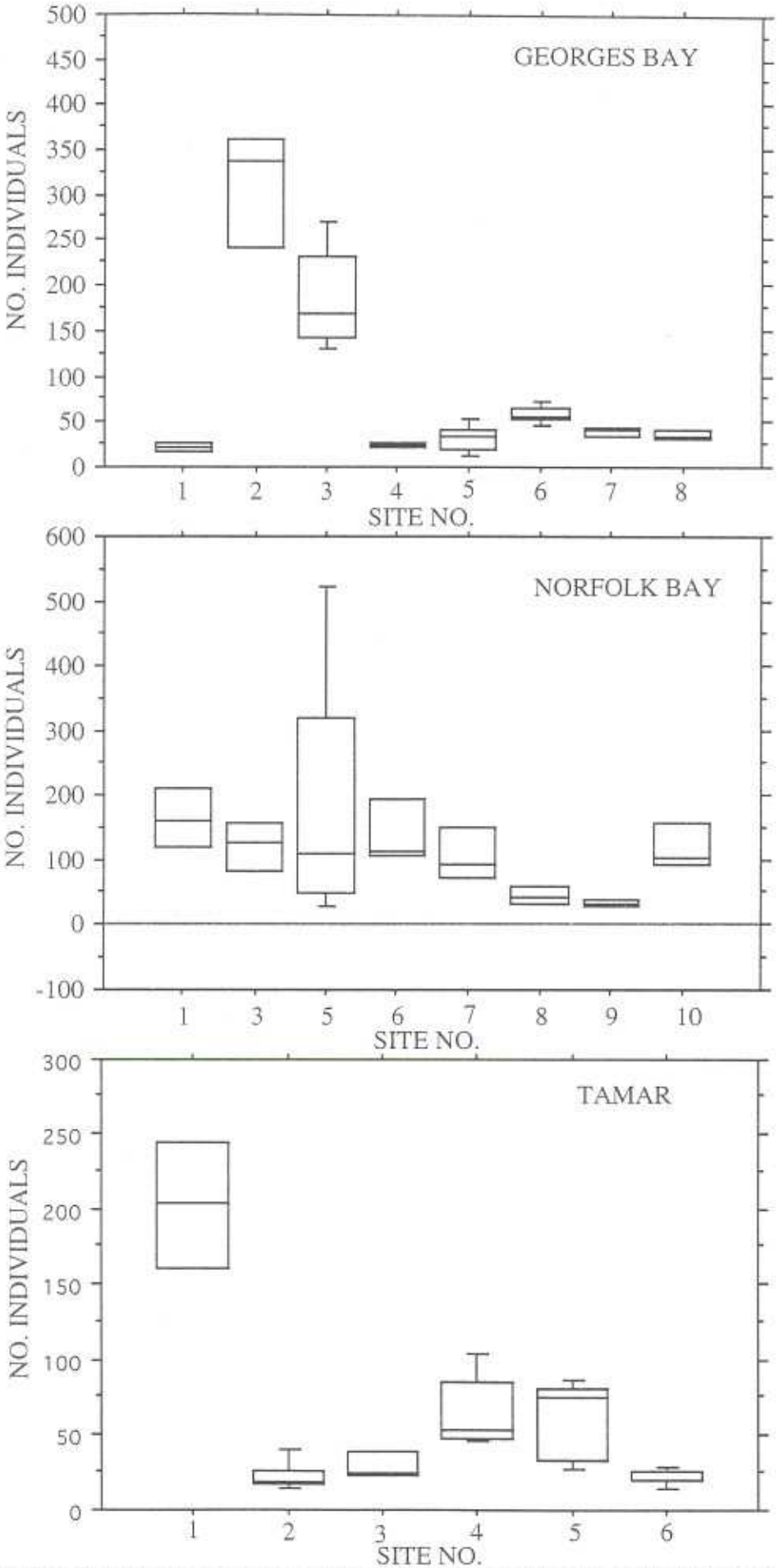


Fig. 4. Box plots for no. individuals per core from habitat sites. Middle horizontal line is the median; upper and lower boundaries of the box are 25 and 75 percentiles, and the vertical bars encompasses the maximum and minimum values. Bars do not appear on plots with only three replicates.

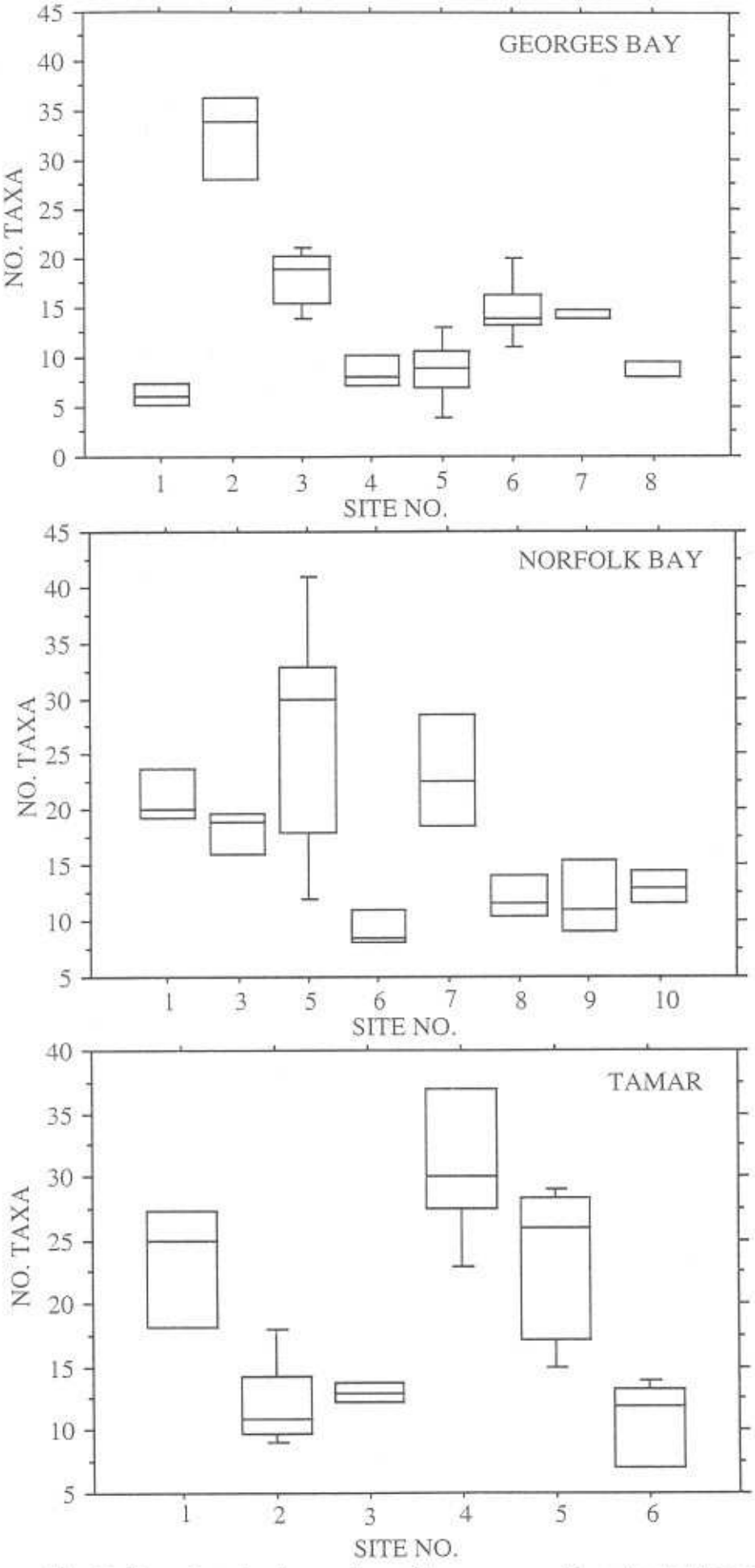


Fig. 5. Box plots for the number of taxa per core from the habitat sites.

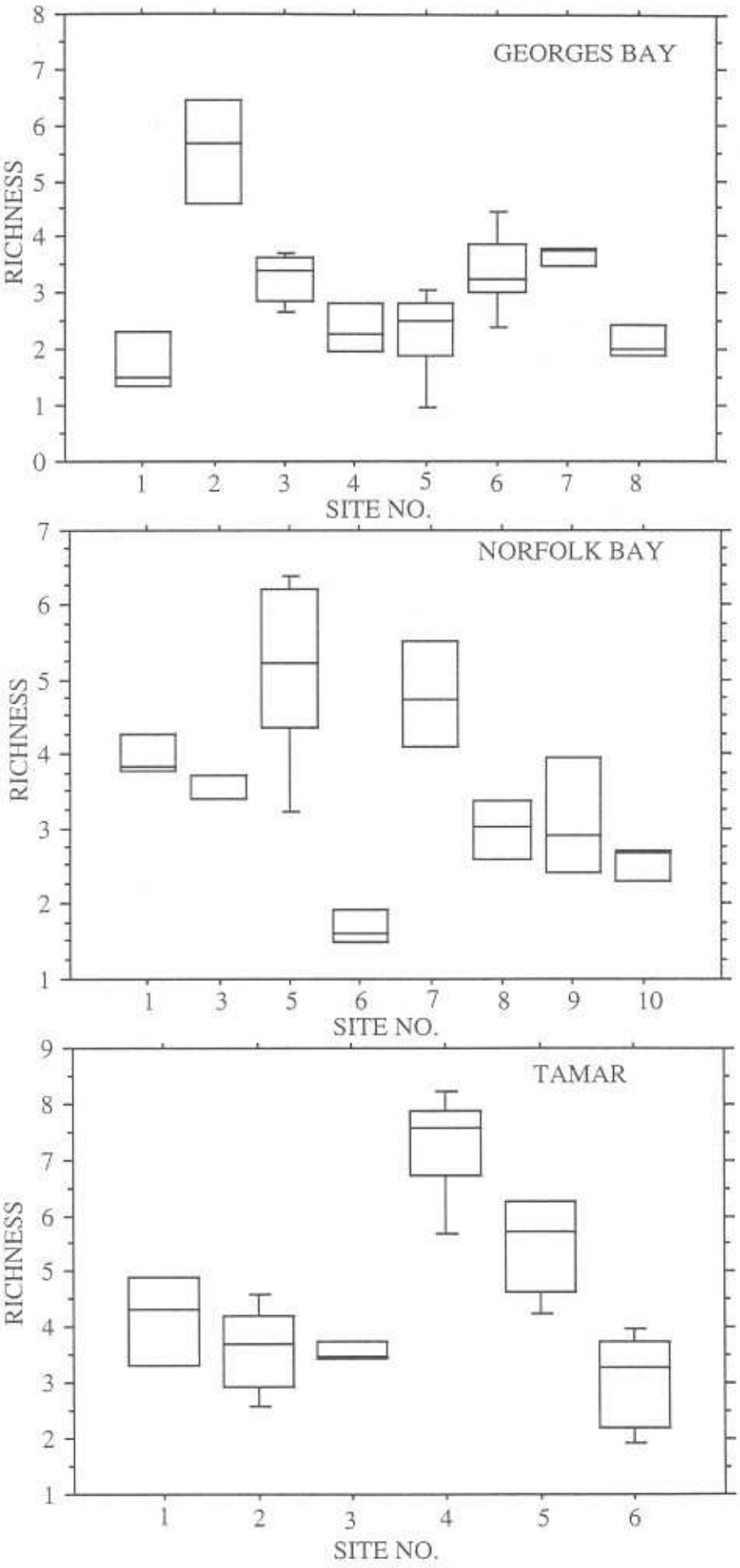


Fig. 6. Box plots for the richness indices calculated for the habitat sites.

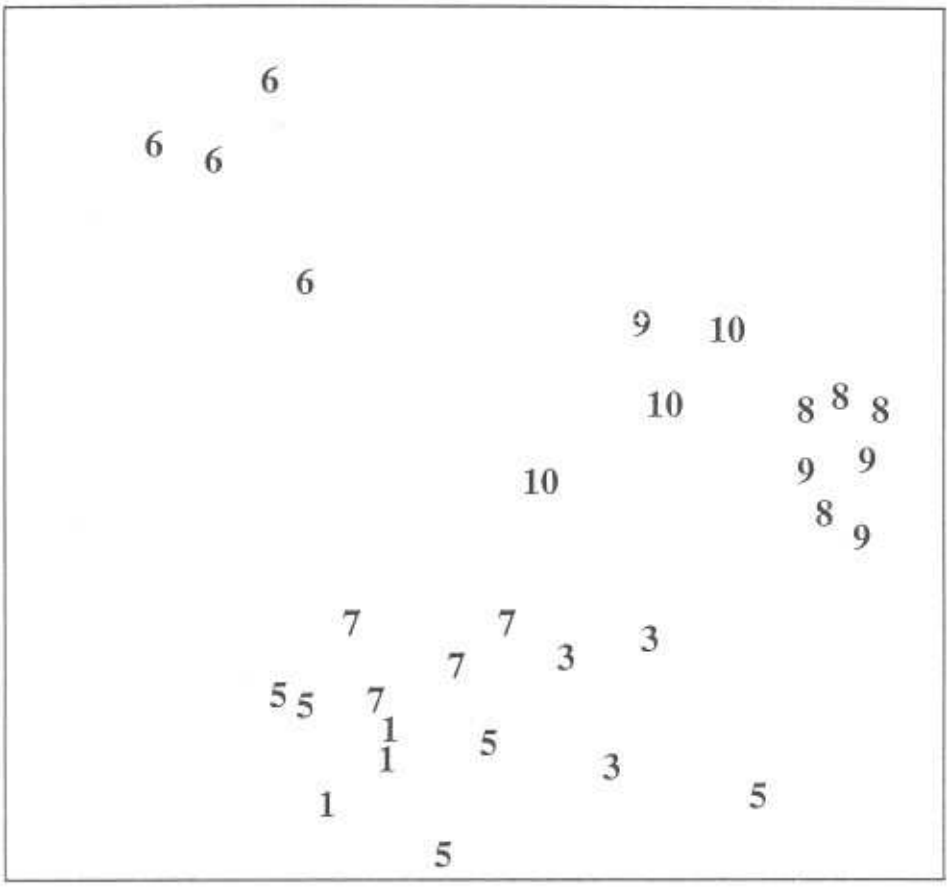


Fig. 7. Ordination plot for habitat samples collected from Norfolk Bay (Stress = 0.14).

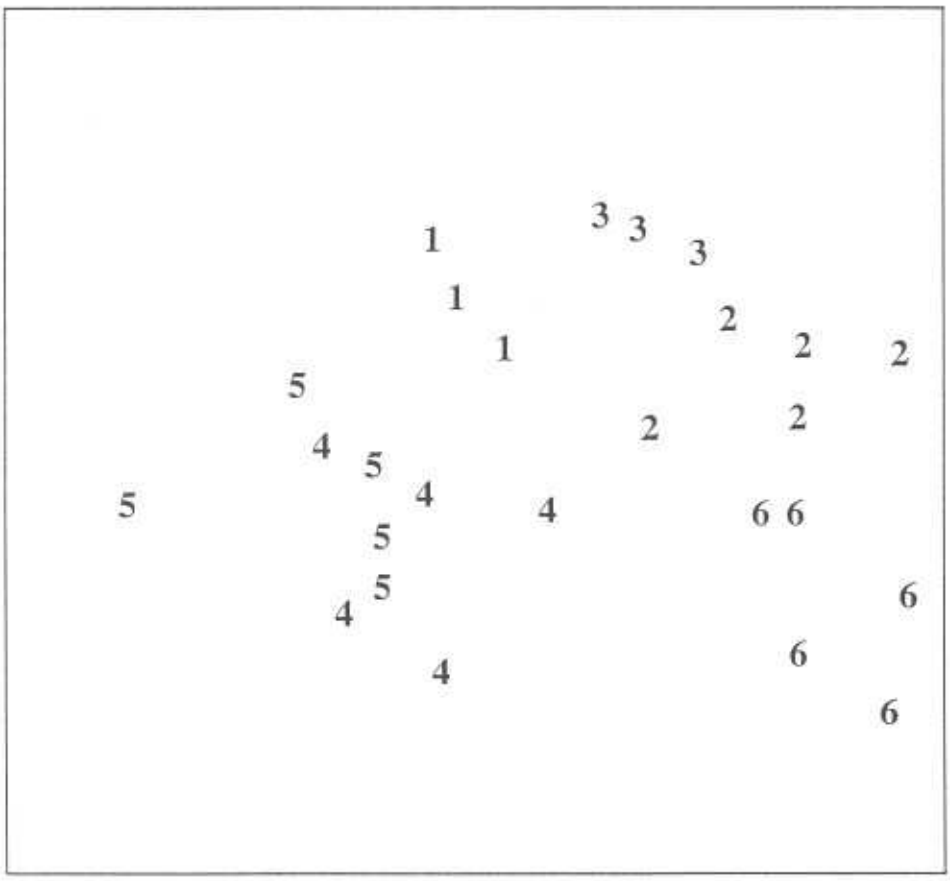


Fig. 8. Ordination plot for habitat samples collected from the Tamar River (Stress = 0.15).

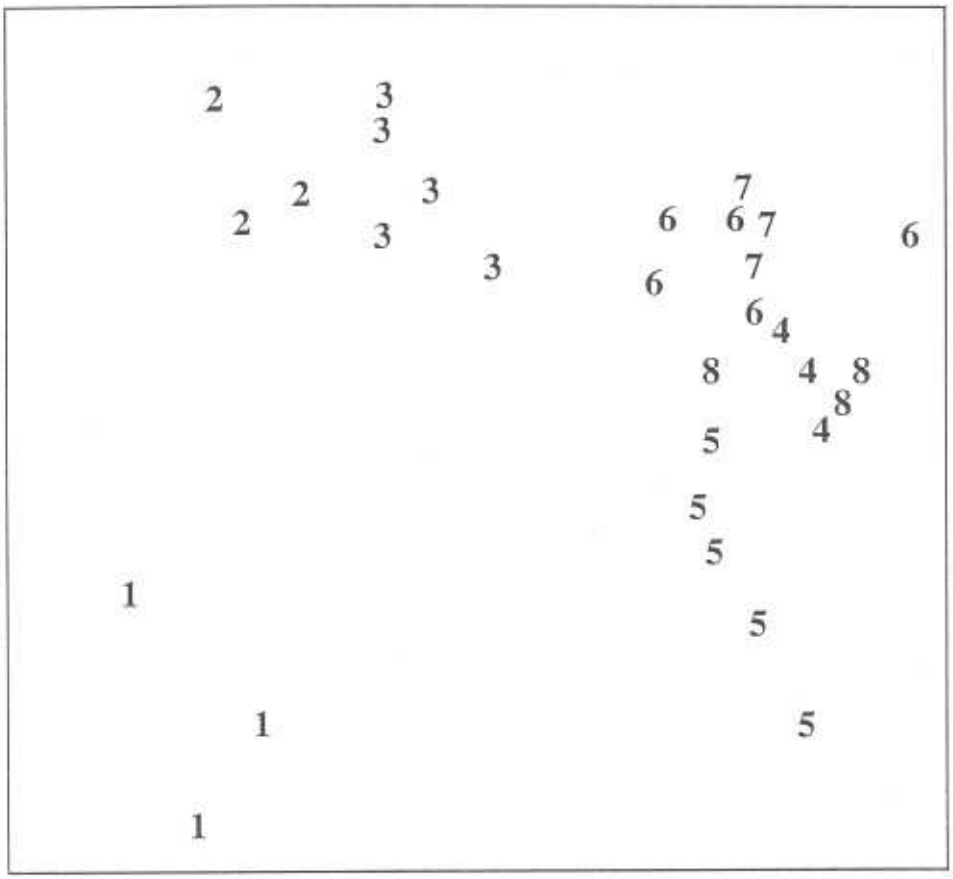


Fig. 9. Ordination plot for habitat samples collected from Georges Bay (Stress = 0.15).

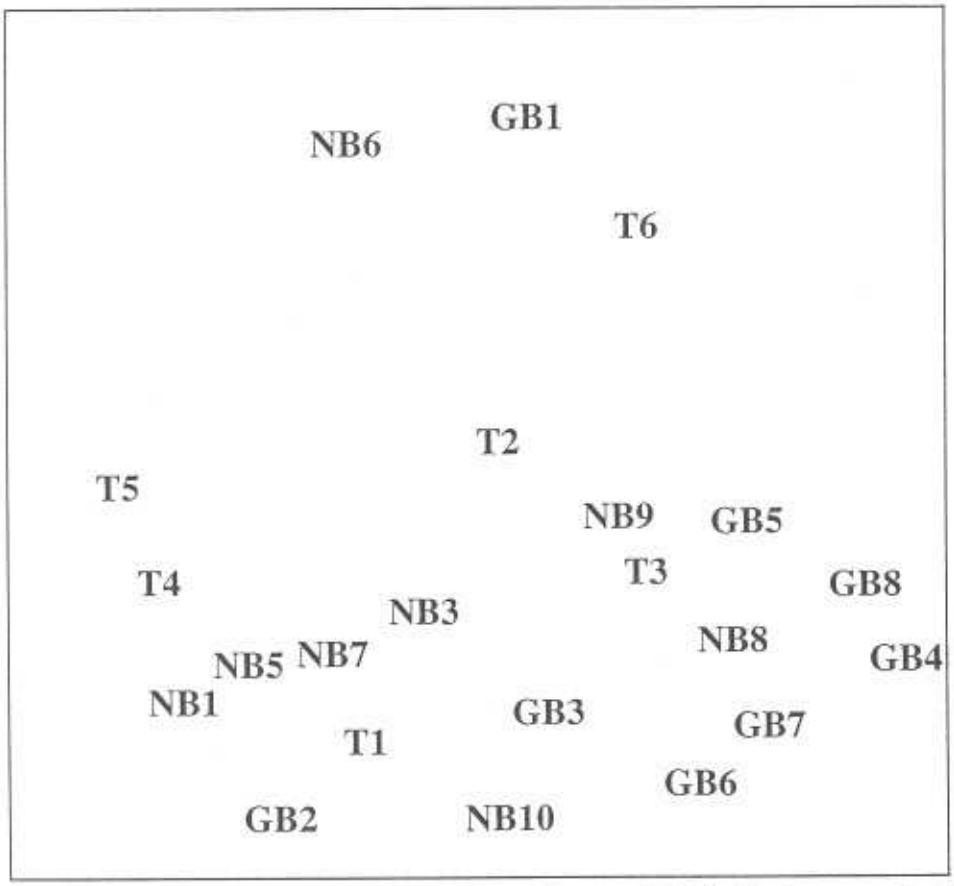


Fig. 10. Ordination plot for the habitat sites (Stress = 0.17). To decrease the figure's complexity, data have been reduced by averaging the numbers of individuals for each taxa collected in the replicates from each site into a composite sample.

CHAPTER 3 - SEASONAL STUDY

Methods

Benthic core samples were taken seasonally between autumn 1995 and summer 1996 from two sites in Norfolk Bay, three sites in Georges Bay and four sites in the Tamar River (Table 1). Site numbers are the same as those in Chapter 1. The aim of this component of the study was to describe the temporal patterns in abundances of individuals and taxa, the range of these variables and any temporal changes in the intersite community relationships.

Results

Numbers of individuals and taxa

In both Norfolk Bay and Georges Bay no consistent seasonal pattern was apparent, with peaks in the median number of individuals occurring in both winter and summer (Fig. 1). In contrast, all Tamar River sites showed maximum number of individuals in summer.

The highest median density was recorded during winter from the unvegetated Norfolk Bay site 6, with median densities for this site similar to those for the adjacent *Heterozostera* site 5 in all other seasons. The second highest median density was also recorded from an unvegetated site (summer, Tamar site 2). The lowest median density was recorded in winter from the unvegetated Tamar site 6. In autumn and summer this site also had lower densities than the nearby *Posidonia* sites 4 and 5, although densities were similar in spring. In autumn, winter and spring the Georges Bay unvegetated site 5 had lower densities than the *Heterozostera* sites 3 and 6, however summer densities for site 5 were similar to those for site 3.

All sites in all three areas had high values for the numbers of taxa recorded per core during spring and/or summer, indicating that species diversity is highest during this time of the year (Fig. 2). An exception was Tamar site 5 which had highest number of taxa in winter, the highest number recorded for any site in any season.

Number of taxa recorded from unvegetated sites were generally less than that recorded from vegetated sites. An exception to this was the Tamar unvegetated site 2 where winter, spring and summer samples contained similar numbers of taxa to Georges Bay and Norfolk Bay *Heterozostera* sites. No seasonal samples were taken at the *Heterozostera* sites were in the Tamar River.

Multivariate analysis of individual sites

There was no consistent pattern for the seasonal relationships between the species assemblages found at the different sites (Figs. 3-11). Autumn assemblages at the unvegetated Tamar site 2 and Norfolk Bay site 6 and *Heterozostera* sites Norfolk Bay site 5 and Georges Bay site 5 were markedly different from the assemblages at these sites for other times of the year (Figs. 3,4,6,8). Also, generally the similarity between replicates were lower in the autumn samples than for replicates collected at other times of the year. An exception to this was the Norfolk Bay site 6 samples where the similarity between autumn replicates were comparable to those for the other times of the year.

There were two major assemblages found at the Georges Bay *Heterozostera* site 3; one for autumn and winter, the other for spring and summer (Fig. 5). Similarity indices between most of the Georges Bay *Heterozostera* site 6 replicates were comparable (Fig. 7). This indicates that throughout the year there was very little change in the assemblage at this site.

The Tamar River *Posidonia* sites 4 and 5 possessed a low level of similarity between replicates (Figs. 9,10). There appeared to be some clustering of replicates from the different seasons, particularly summer, indicating some temporal changes in the assemblages. The Tamar unvegetated site 6 possessed a distinct assemblage in summer to that in spring and autumn. The winter samples were extremely different to those collected at other times of the year with a large amount of between replicate variability (Fig. 11).

Multivariate analysis of all sites

Because of the large numbers of replicate samples data reduction was necessary to allow easy interpretation of this analysis. Numbers of taxa in the seasonal replicates from each site were averaged to give a single sample for each location and a multivariate analysis of this data undertaken.

The ordination plot reveals a fairly complex interrelationships between the different sites (Fig. 12). Only two sites possessing similar species assemblages were Tamar *Posidonia* sites 4 and 5. The two unvegetated sandy beach sites Tamar site 6 and Norfolk Bay site 6 were most similar to each other and clearly contained assemblages distinct from the other sites. These two sites were also the sites with the greatest seasonal variability. The samples from the unvegetated Tamar site 2 in autumn, winter and spring were distinct from those at other sites. The summer sample was as similar to those from Norfolk Bay site 5 as to the other samples collected from Tamar site 2.

The samples from the unvegetated Georges Bay site 5 in autumn, winter and spring were distinct from those at other sites. The summer sample was as similar to autumn, winter and spring samples from Georges Bay site 6 as to the other Georges Bay site 5 samples. The summer sample from Georges Bay site 6 was more similar to the other *Heterozostera* site in Georges Bay (site 3), than samples collected at other times of the year from Georges Bay site 6.

Autumn and winter samples from Georges Bay site 3 were similar to the summer sample from Georges Bay site 6. The spring and summer samples from Georges Bay site 3 were as similar to the winter, spring and summer samples from Norfolk Bay *Heterozostera* site 6 as the other samples collected from Georges Bay site 3 and the summer sample from Georges Bay site 6.

There is a very complex relationship for the Norfolk Bay *Heterozostera* site 5. The autumn sample was similar to the spring sample from the Tamar *Posidonia* site 4. The Norfolk Bay site 5 winter, spring and summer samples showed comparable similarities to the summer samples from Tamar unvegetated site 2 and the spring and summer samples from Georges Bay *Heterozostera* site 3.

Discussion

Numbers of individuals and taxa

The absence of a general seasonal pattern in our data may be because seasonal variability does not exist; or, because it is on a similar, or smaller scale to the non-seasonal temporal and spatial variability in the samples. Despite the lack of temporal tends, the data provides a useful insight into the extent of temporal variability and its effect on interpretation of data from a single sampling time such as provided in Chapter 2.

It is generally found that seagrass beds support a higher faunal density and diversity than adjacent unvegetated areas (Kikuchi & Peres 1977; Lewis 1984; Peterson & Black 1986; Hutchings *et al.* 1988; Orth 1992; Edgar *et al.* 1994) due to the larger number of microhabitats available and diversity of food resources. However, these results provide further evidence that in Tasmania seagrass habitats do not have consistently higher invertebrate densities than

surrounding unvegetated areas. While highest densities occurred at unvegetated sites they were also the sites with the greatest variability. Also, our results show that while invertebrate diversities are generally higher in vegetated than unvegetated habitats, at times both habitats can support similar diversities.

When comparing sites for marine reserves the fact that different sites had maximum densities and diversity at different times of the year will have considerable implications if these variables are used as criteria for selecting reserve sites. Comparison between sites and habitats would only be valid if based on a series of samples collected over a period of at least one year. Within season sampling should also be undertaken to determine the extent of temporal variability in the invertebrate assemblages.

Multivariate analysis of individual sites

The multivariate analysis reveals considerable temporal changes in the invertebrate assemblages at the different sites. A study spanning at least two years would be required to ascertain if these differences were seasonal or non-seasonal (ie. if similar assemblages occurred each year). As with the results from the analysis of the univariate data this result emphasises the fact that invertebrate assemblages at the sites are not stable and show considerable temporal variability.

The analysis also suggests that if it is necessary to undertake single time samples for soft-bottom invertebrate fauna autumn is the least appropriate season. This should also be taken into account when interpreting patterns of species assemblages from the autumn data in Chapter 2. Four out of the nine sites had markedly different assemblages in autumn to that present at other times of the year. Variability between replicates also tends to be highest at this time of year.

The winter replicates from Tamar site 6 showed the most aberrant pattern. These replicates were characterised by low similarity with replicates from other times of the year and high between replicate variability. This was due to the site being under sampled, less than 10 individuals being collected per core. This highlights the difficulty of using a standard sampling method for all sites at all times of the year. This under sampling highlights the problem of obtaining a balance between collecting sufficient replicate samples and the time required to sort samples. Considering the wide range of densities encountered in this study future studies of soft-bottom benthic invertebrates will require different levels of sampling to be undertaken for different sites and at different times of the year.

Multivariate analysis of all sites

Caution is required in interpreting these results because only one year has been sampled. It is not known if the temporal shifts in relationships that have been described are truly seasonal, ie. recur every year, or if they are simply the product of variability between different sets of samples.

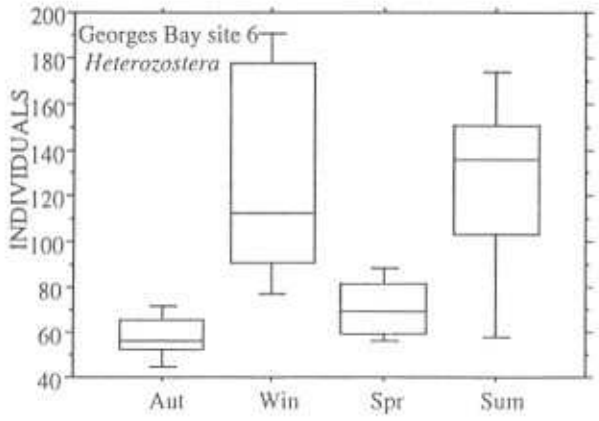
This analysis reveals that sampling in the different seasons indicates different interrelationships between assemblages from different sites. For example, the autumn samples indicate that Norfolk Bay *Heterozostera* site 5 is more similar to the *Posidonia* sites at the mouth of the Tamar River than the *Heterozostera* sites in Georges Bay. However, the winter, spring and summer samples suggest a closer relationship with Georges Bay *Heterozostera* site 3. Another example of the seasonal effect on interpretation is that the summer samples indicate the two *Heterozostera* sites in Georges Bay, sites 3 and 6, possessed very similar assemblages, while samples from other times of the year suggest these sites have different assemblages.

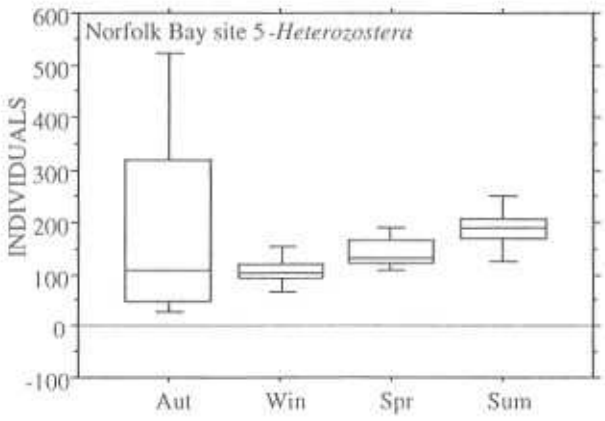
When designing a study to identify representative habitats suitable for management as marine reserves, differences in interrelationships caused by temporal variations in the invertebrate

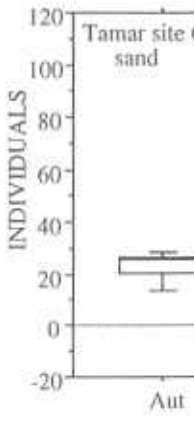
assemblages should be investigated. Seasonal sampling should be undertaken for at least one year and preferably over a number of years to identify the effect of temporal variability in patterns of species assemblages.

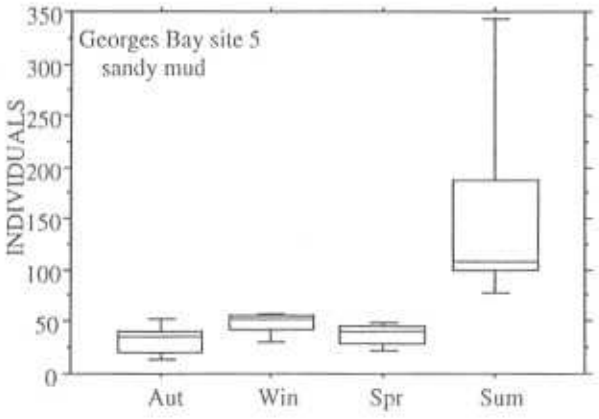
Table 1. Details of sites sampled for the seasonal component of the study. Site numbers in each area are the same for those in Chapter 2.

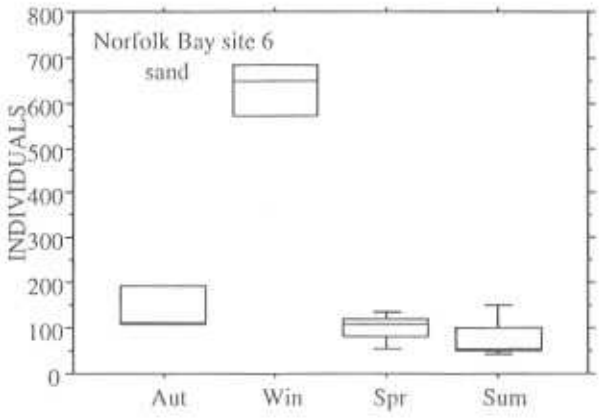
AREA	SITE NO. - NAME	DEPTH RANGE	HABITAT TYPE	SEASONAL SAMPLE DATES
Norfolk Bay	5 - Lime Bay -	3-4m	*Heterozostera*	13/4/95; 15/8/95; 19/10/95; 23/2/96
	6 - Lime Bay - unveg.	1-3m	sand	22/5/95; 15/8/95; 19/10/95; 23/2/96
Georges Bay	3 - Steiglitz Beach	3-4m	*Heterozostera*	1/6/95; 31/7/95; 3/10/95; 8/1/96
	5 - Moulting Bay	3-4m	sandy mud	29/5/95; 31/7/95; 3/10/95; 8/1/96
	6 - Outer Moulting Bay	2-3m	*Heterozostera*	30/5/95; 1/8/95; 3/10/95; 8/1/96
Tamar River	2 - West Arm	2-4m	sandy mud	4/5/95; 25/7/95; 25/9/95; 23/1/96
	4 - Lagoon Bay	2-4m	*Posidonia*	4/5/95; 25/7/95; 25/9/95; 23/1/96
	5 - North West Bank	2-4m	*Posidonia*	4/5/95; 25/7/95; 25/9/95; 23/1/96
	6 - Greens Beach	2-4m	sand	4/5/95; 25/7/95 25/9/95; 23/1/96

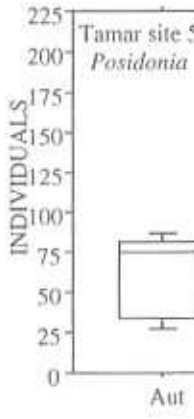


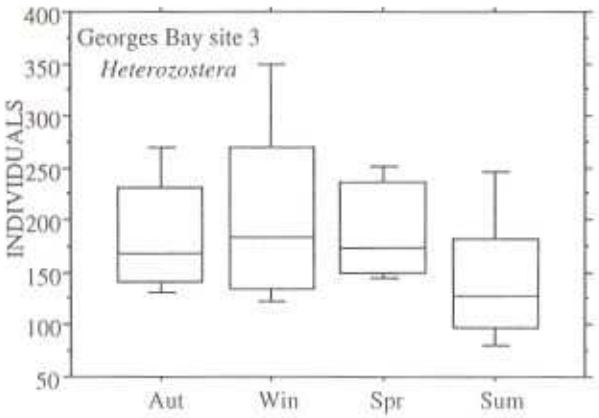


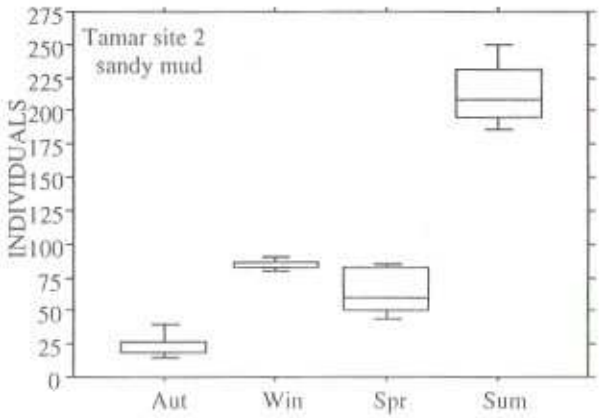












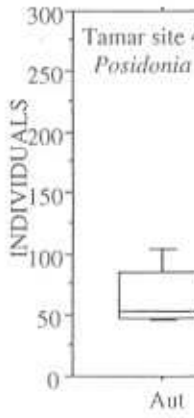


Fig. 1 Box plots for the number of individuals per core collected at each site in the seasonal samples.

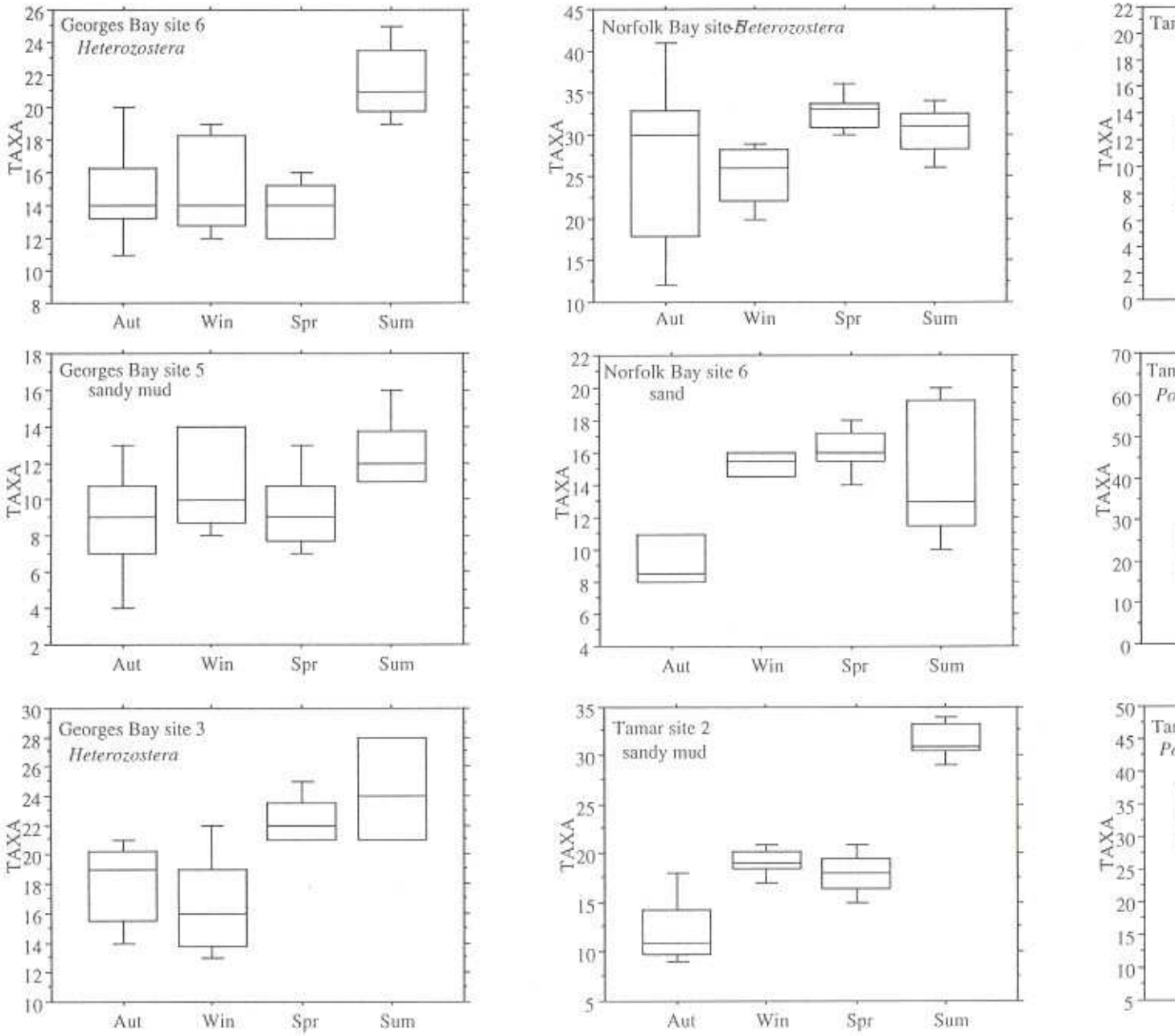


Fig. 2. Box plots for the number of taxa per core collected at each site in the seasonal samples.

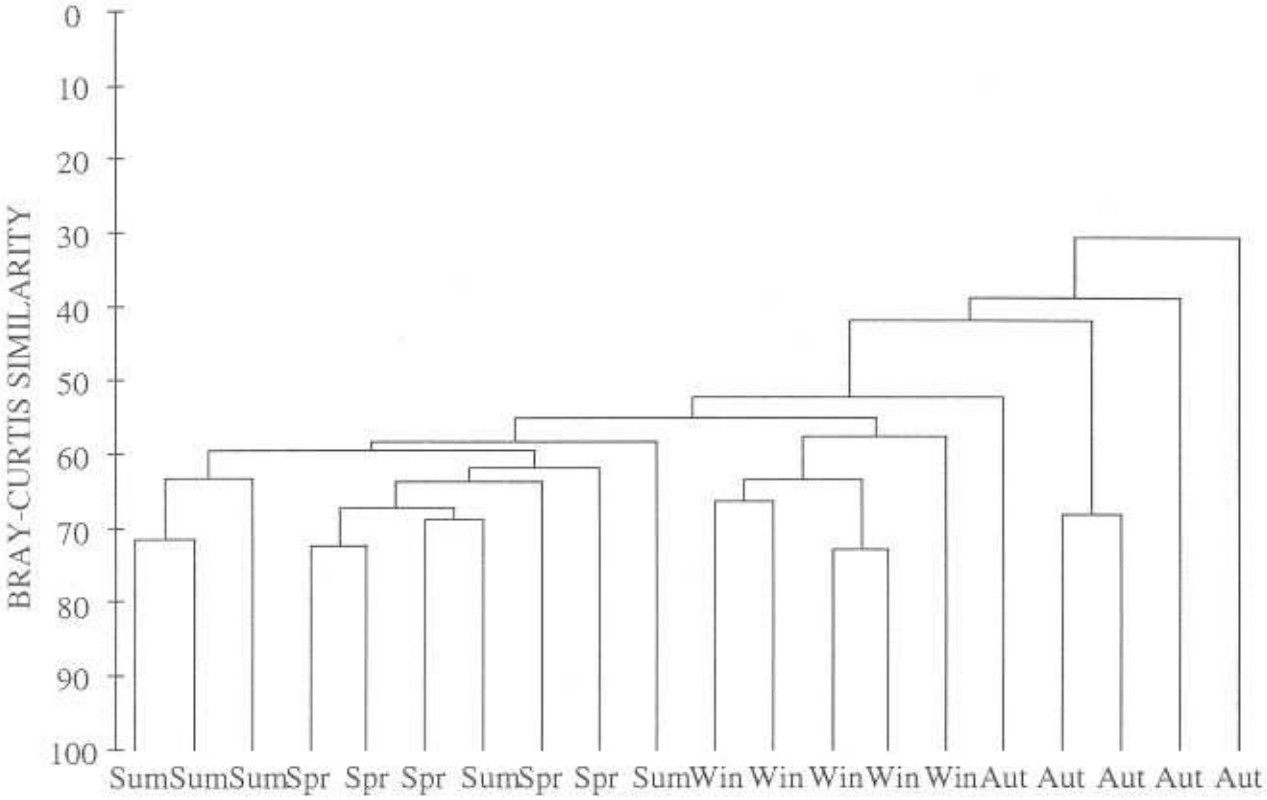


Fig. 3. Hierarchical agglomerative clustering of Norfolk Bay Site 5 seasonal data using group average linking.

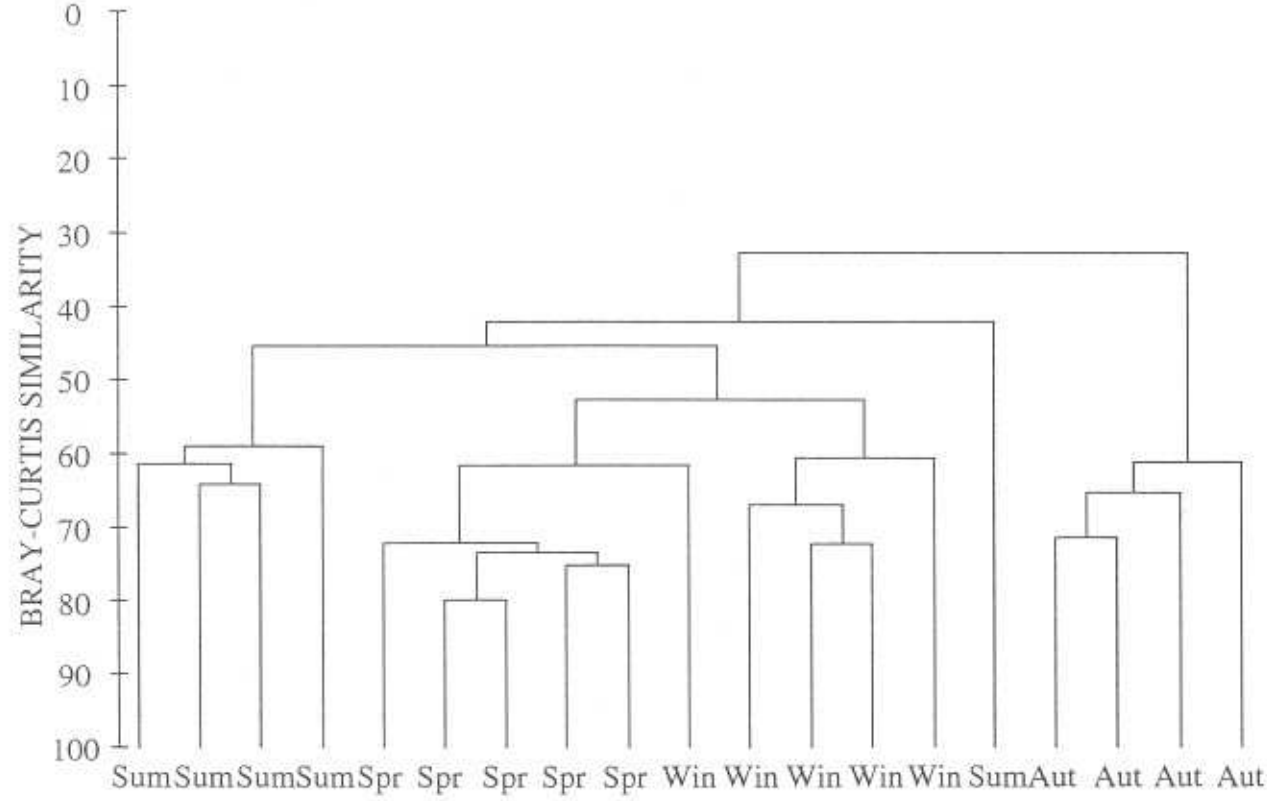


Fig. 4. Hierarchical agglomerative clustering of Norfolk Bay Site 6 seasonal data using group average linking.

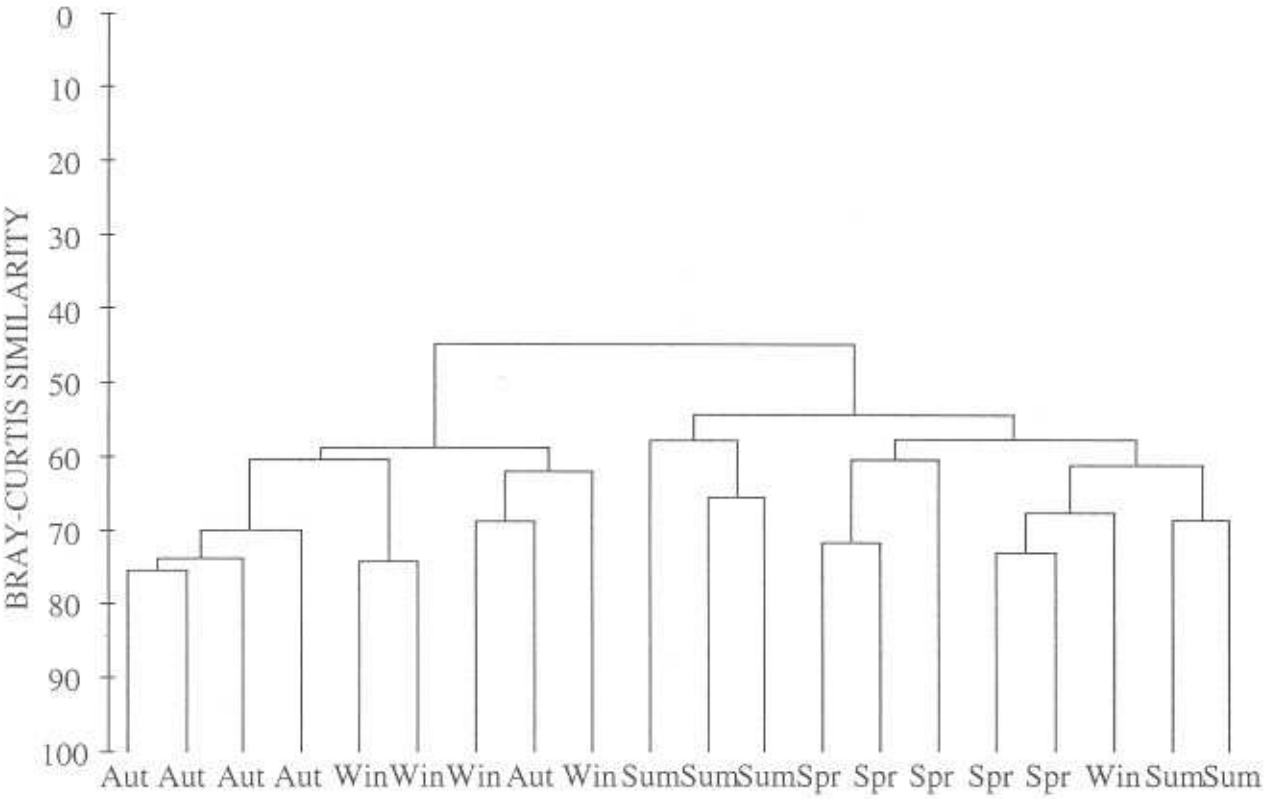


Fig. 5. Hierarchical agglomerative clustering of Georges Bay Site 3 seasonal data using group average linking.

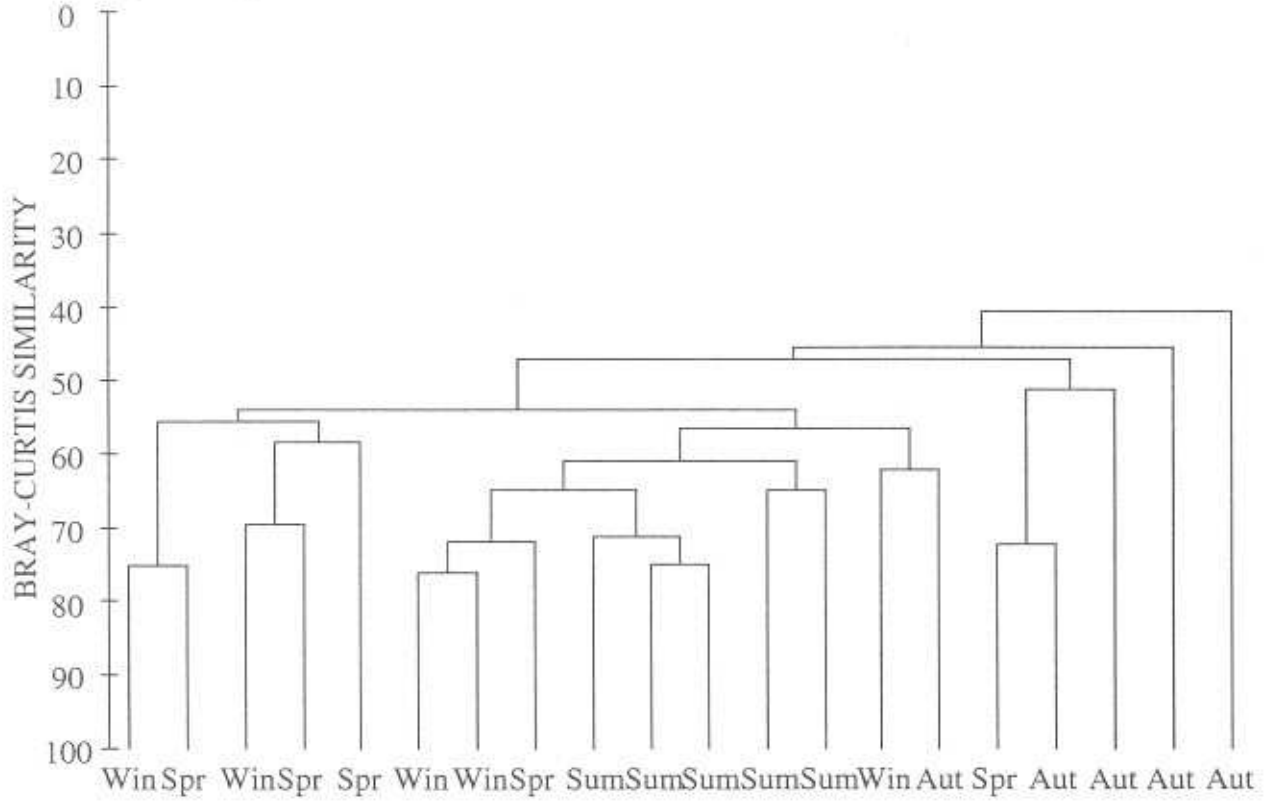


Fig. 6. Hierarchical agglomerative clustering of Georges Bay Site 5 seasonal data using group average linking.

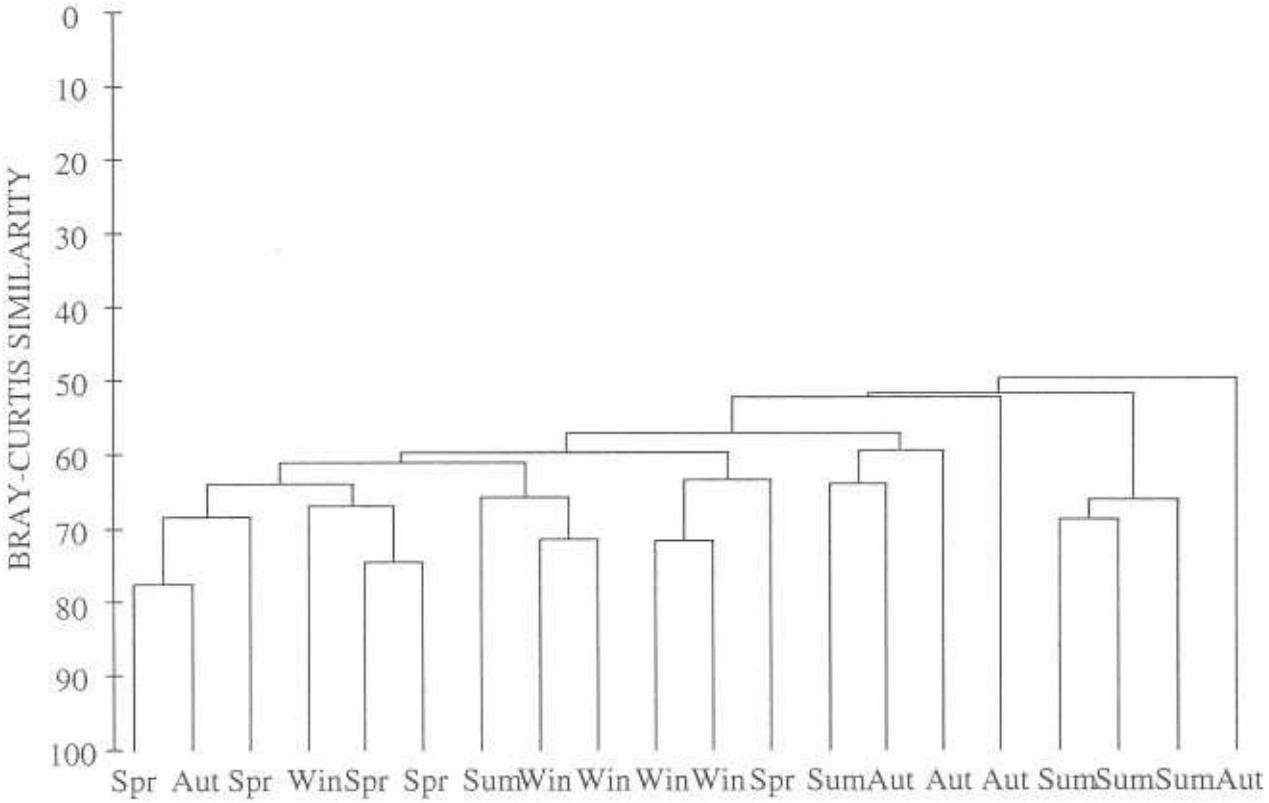


Fig. 7. Hierarchical agglomerative clustering of Georges Bay Site 6 seasonal data using group average linking.

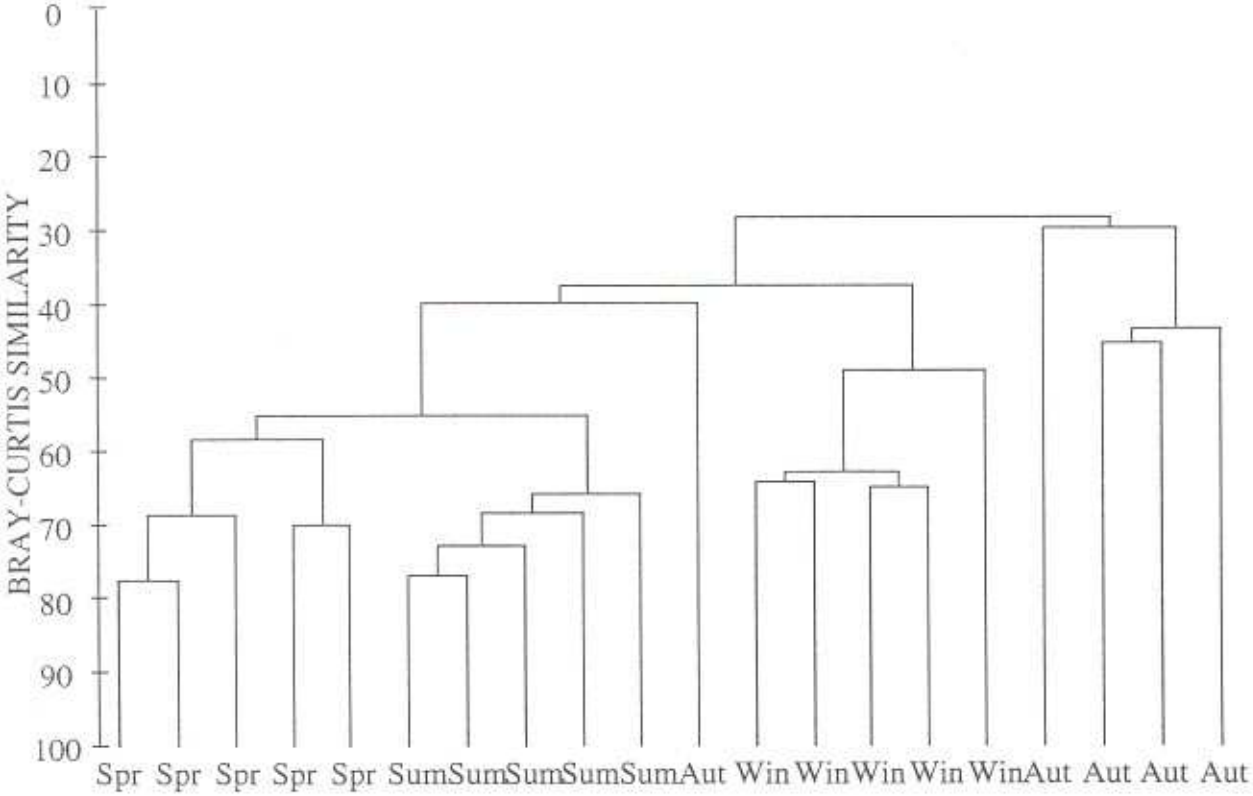


Fig. 8. Hierarchical agglomerative clustering of Tamar Site 2 seasonal data using group average linking.

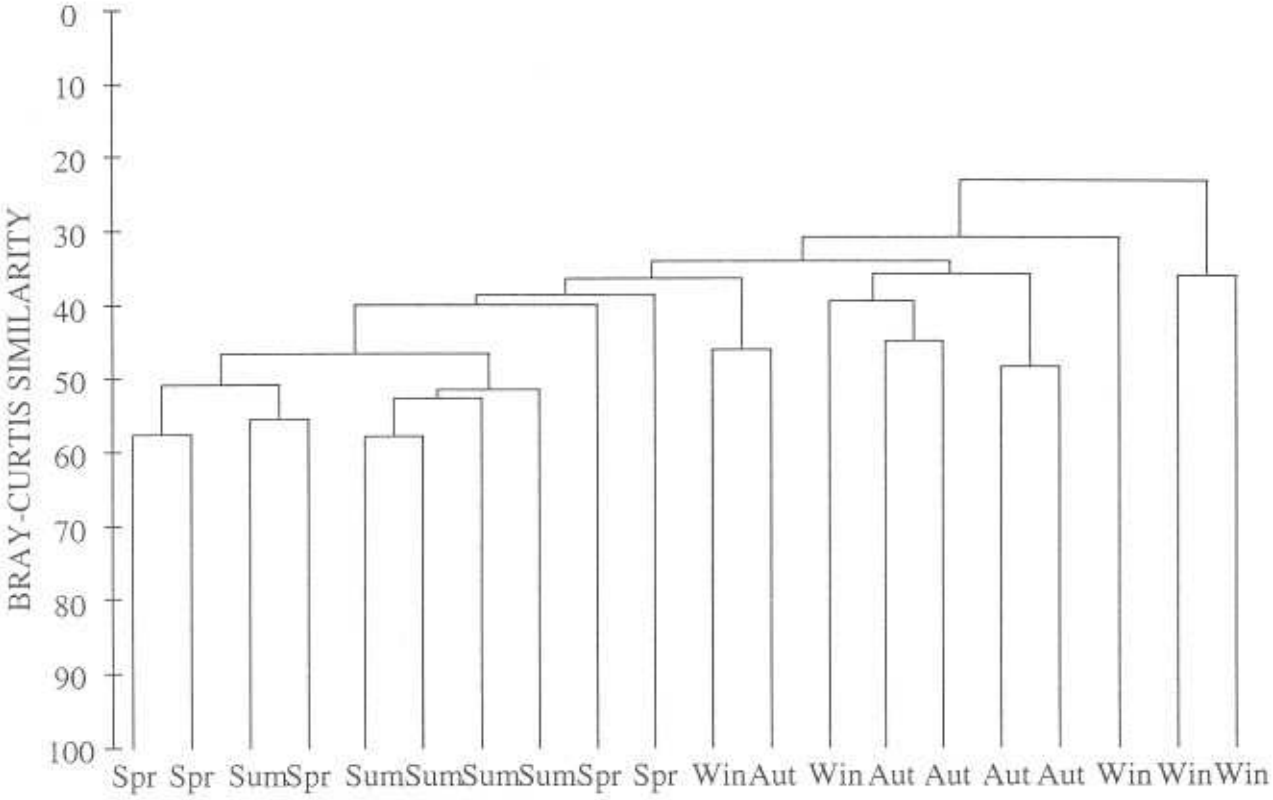


Fig. 9. Hierarchical agglomerative clustering of Tamar Site 4 seasonal data using group average linking.

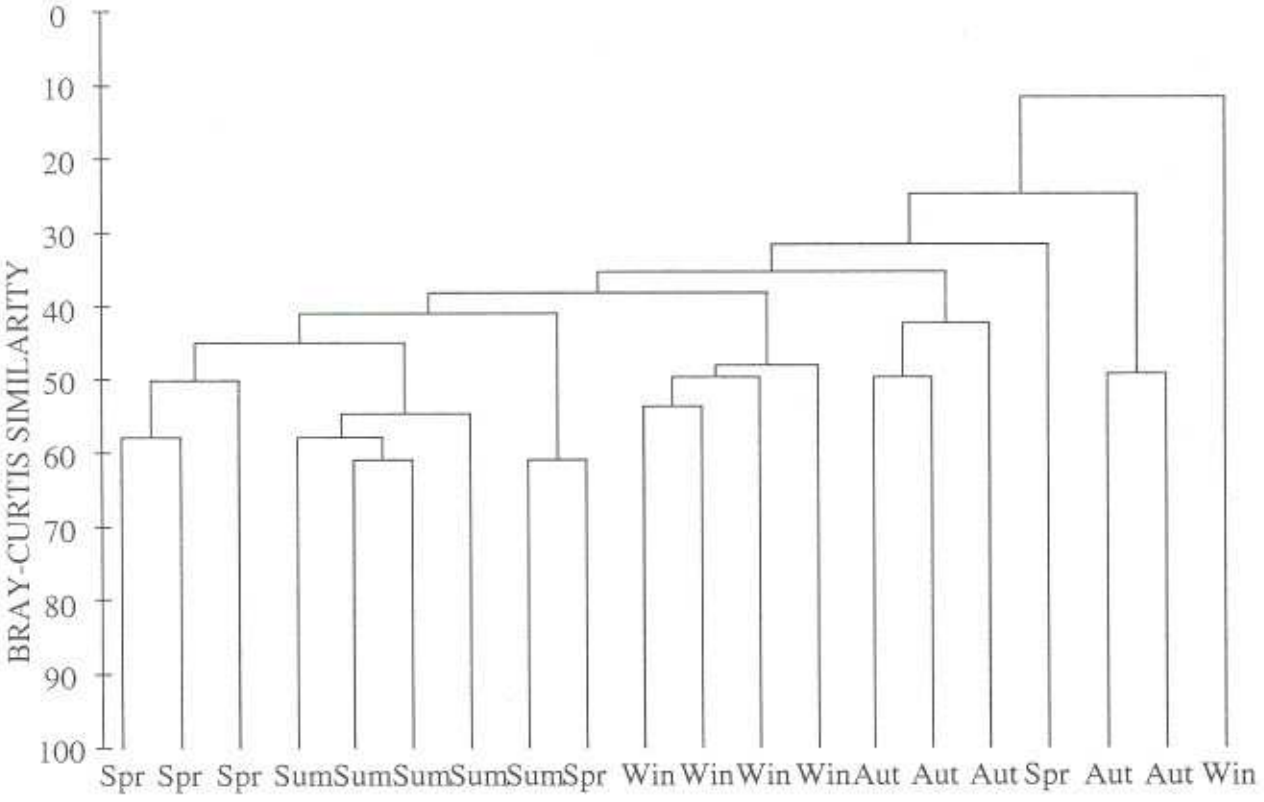


Fig. 10. Hierarchical agglomerative clustering of Tamar Site 5 seasonal data using group average linking.

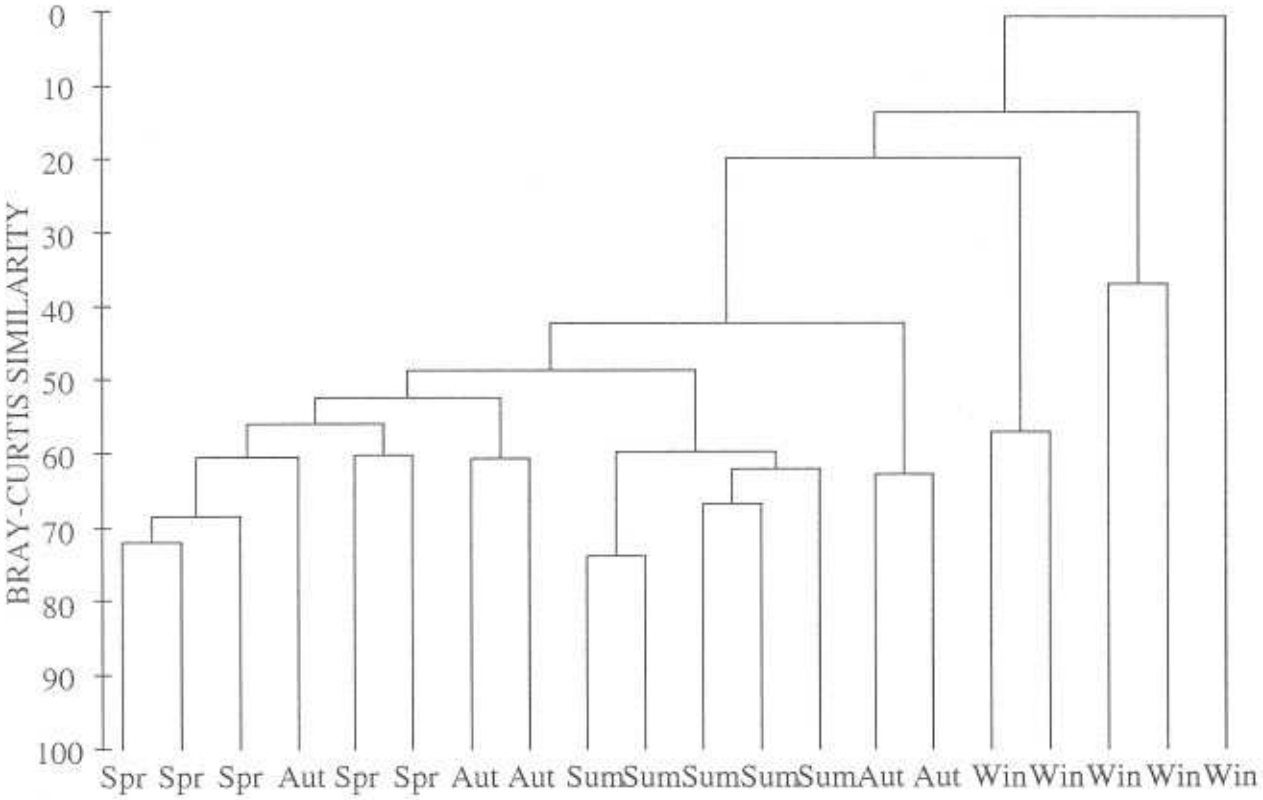


Fig. 11. Hierarchical agglomerative clustering of Tamar Site 6 seasonal data using group average linking.

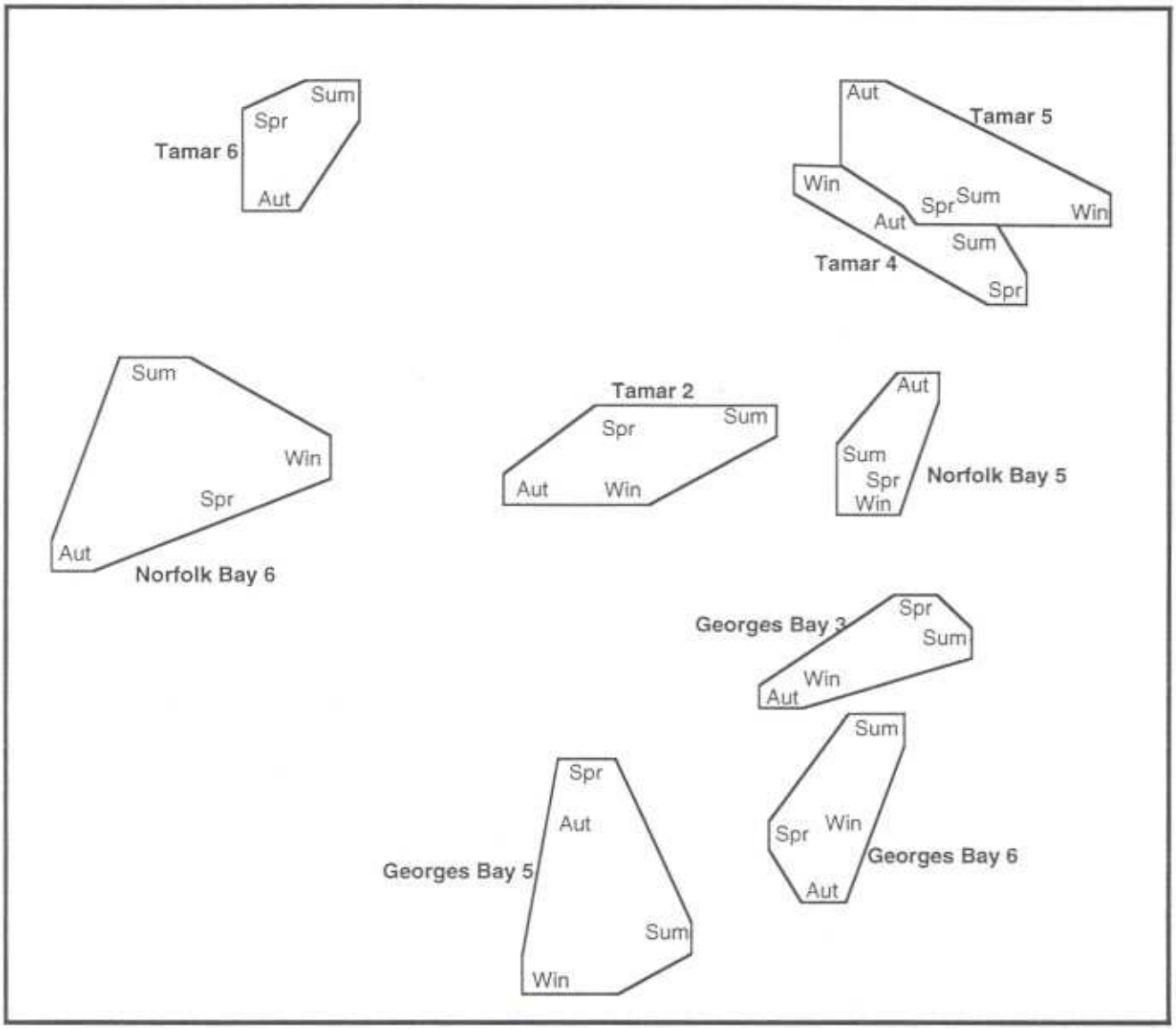


Fig. 12. Ordination plot for the seasonal data (Stress = 0.14). To decrease the figures complexity, data have been reduced by averaging the numbers of individuals for each taxa collected in the replicates from each site, during each season, into a composite site/season sample. The Tamar site 6 winter sample was excluded because it was an outlier, and the data unreliable, due to the low numbers of individuals collected per core.

CHAPTER 4 - SNAPSHOT SURVEY

Methods

Benthic core samples were taken between 25 July and 29 August 1995 from twenty-two vegetated and unvegetated sites around Tasmania (Fig.1) (Table 1). The aim of this study was to establish the level of geographical variation within the soft-bottom invertebrate benthic assemblages around the state.

The seasonal study revealed that because different sites may have peaks for densities and diversity at different times it is not valid to compare sites based on these indices for a single time survey such as this. However, this survey does indicate the range of values that occurs within and between haitats over a large geographic range.

Results

Numbers of individuals and taxa

The lowest densities of individuals, less than 10 per core, occurred at the three sandy beach sites along the north coast of Tasmania (T6, S and RB) (Fig. 2). The highest density of 650 individuals per core was collected from a sandy beach site (NB6) in south-east Tasmania. This high number is in contrast to the low numbers of individuals found at this site during all other seasons (see Chapter 3, Fig. 1). In general, however, vegetated sites had higher densities than unvegetated sites with highest densities at marine dominated vegetated sites. However, not all marine, vegetated sites possessed high densities, such as Tamar 4 (T4) and Robins Island (RI). There was no trend apparent for the numbers of individuals with regard to geographic location.

Five sites showed low numbers of taxa per core. The three northern sandy beach sites (T6,S,RB) and the two Macquarie Harbour sites (Fig. 3) all containing less than 10 taxa per core. The Waterhouse Island (WI) site had an exceptionally high number of taxa per core compared to the other sites. Three other sites, Little Musselroe Bay (LMB1), Tamar 5 (T5) and Spring Bay 2 (SB2) also possessed high numbers of taxa per site. These four sites are all marine dominated vegetated sites, WI, LMB1 and T5 being *Posidonia* sites, and SB2 a *Heterozostera* site.

Multivariate analysis of all sites

The cluster analysis of samples using abundance data revealed very low similarity between any pair of samples, and produced a high degree of chaining (Fig. 4). The sandy beach Tamar 6 site showed the least similarity, which may reflect the under sampling at this site. While there was faunal similarities in *Posidonia* sites there was little distinct separation from other sites. The overall analysis indicates there is very little relationship between the species assemblages at the different sites sampled. An analysis based on presence - absence data (Fig. 5) produced a similar results, indicating differences in species composition for the sites and not just differences in species abundances.

Discussion

Numbers of individuals and taxa

One of the problems with interpretation of data from a snapshot survey is the difficulty of interpreting how recent environmental conditions may have impacted on the sites. Three of the sites (T4,5,6) near the mouth of the Tamar estuary were possibly impacted by oil from the grounding of the *Iron Baron* 15 days before the samples were collected.

The seasonal data revealed the low densities recorded from Tamar 6 were atypical compared to those from the rest of the year. However, as the other two northern sandy beach sites also had exceptionally low densities it is unlikely this was an impact of the oil spill. Also, it is unlikely to be a seasonal pattern for northern sandy beaches, because the east coast sandy beach of Little Musselroe Bay 2 is at a similar latitude to the three north coast sites, and did not have exceptionally low density of individuals. It is possible sea conditions before sampling influenced the numbers of individuals found on these exposed sandy beaches. If true, the different aspect for the eastern and northern beaches could explain the differences in abundances for these sites, and highlights the impact of recent physical events on the invertebrate community.

The highest number of taxa per core were recorded from vegetated sites that were most marine dominated. Tamar site 4 was a notable exception to this pattern, being a marine sites with dense vegetation where the number of taxa per core were typical of most other vegetated sites. The seasonal data revealed that numbers of taxa per core for Tamar site 4 were at there lowest in the snapshot survey, and at their highest for Tamar site 5. Whether these differences were the result of normal variability or were an impact of the oiling is unknown.

Both sets of samples from Macquarie Harbour were characterised by low numbers of taxa. As well as being geographically separated from the other sites, salinities in Macquarie Harbour are much lower than for the other areas sampled. Consequently these differences may be geographical or physical.

Multivariate analysis of all sites

Multivariate analysis reveals the levels of variability between habitats sampled between both near and geographically separated sites. As discussed in Chapter 2, several studies have found that the principal determinant of the invertebrate species composition is not habitat type, but a range of environmental conditions, principally sediment and salinity characteristics (Collett *et al.* 1984; Edgar 1990; Hutchings *et al.* 1991). The present results also suggest that such physical factors are important determinants of the invertebrate faunal composition in Tasmanian soft-bottom habitats. Hence, similar to the conclusions in Chapter 2, the results suggest that in Tasmania, in order to cover the full range of inshore soft-bottom invertebrate assemblages marine reserves should encompass soft-bottom habitat types covering a broad range of environmental conditions. However, in order to maximise invertebrate abundance and diversity this should be particularly targeted at marine dominated seagrass sites.

The results are unexpected for the two *Posidonia* sites from the mouth of the Tamar Estuary, Tamar 4 and 5. However, the seasonal samples did reveal samples from these two sites were least similar in winter, the period of the snapshot survey. Two geographically close *Heterozostera* sites were Georges Bay sites 3 and 6, however the preceding analysis has already shown samples from these sites were not similar.

The implication of these findings with regards to undertaking sampling to identify different assemblages for incorporation into marine reserves is that a larger number of sites would have to be sampled, or some restriction placed on the range of habitat types sampled.

Table 1. Details of sites sampled for the snapshot survey component of the study.

AREA	SITE NAME	DEPTH	DATE SAMPLED	HABITAT TYPE
South	Cloudy Bay Lagoon **CBL**	2-3m	24/8/95	*Heterozostera*
	Little Taylors Bay **LTB**	2-3m	24/8/95	*Heterozostera/ Halophila*
East	Norfolk Bay **NB5**	3-4m	15/8/95	*Heterozostera*
	Norfolk Bay **NB6**	1-3m	15/8/95	sand
	Spring Bay **SB3**	2-3m	15/8/95	*Heterozostera*
	Spring Bay **SB5**	2-3m	15/8/95	*Heterozostera*
North-east	Georges Bay **GB3**	3-4m	31/7/95	*Heterozostera*
	Georges Bay **GB5**	3-4m	31/7/95	sandy mud
	Georges Bay **GB6**	2-3m	1/8/95	*Heterozostera*
	Ansons Bay **AB**	1-2m	1/8/95	*Heterozostera*
	Little Musselroe Bay **LMB1**	3-5m	3/8/95	*Posidonia*
	Little Musselroe Bay **LMB2**	2-4m	3/8/95	sand
North	Waterhouse Island **WHI**	3-5m	3/8/95	*Posidonia*
	Ransons Beach **RB**	2-3m	3/8/95	sand
	Tamar River **T2**	2-4m	25/7/95	sandy mud
	Tamar River **T4**	2-4m	25/7/95	*Posidonia*
	Tamar River **T5**	2-4m	25/7/95	*Posidonia*
	Tamar River **T6**	2-4m	25/7/95	sand
North-west	Stanley Beach **S**	2-3m	28/7/95	sand
	Robbins Island **RI**	2-4m	27/7/95	*Heterozostera*
West	Macquarie Harbour **MH1**	2-3m	29/8/95	sand
	Macquarie Harbour **MH2**	2-3m	29/8/95	*Ruppia*

Fig. 1. Map showing distribution of snapshot survey sampling sites around Tasmania

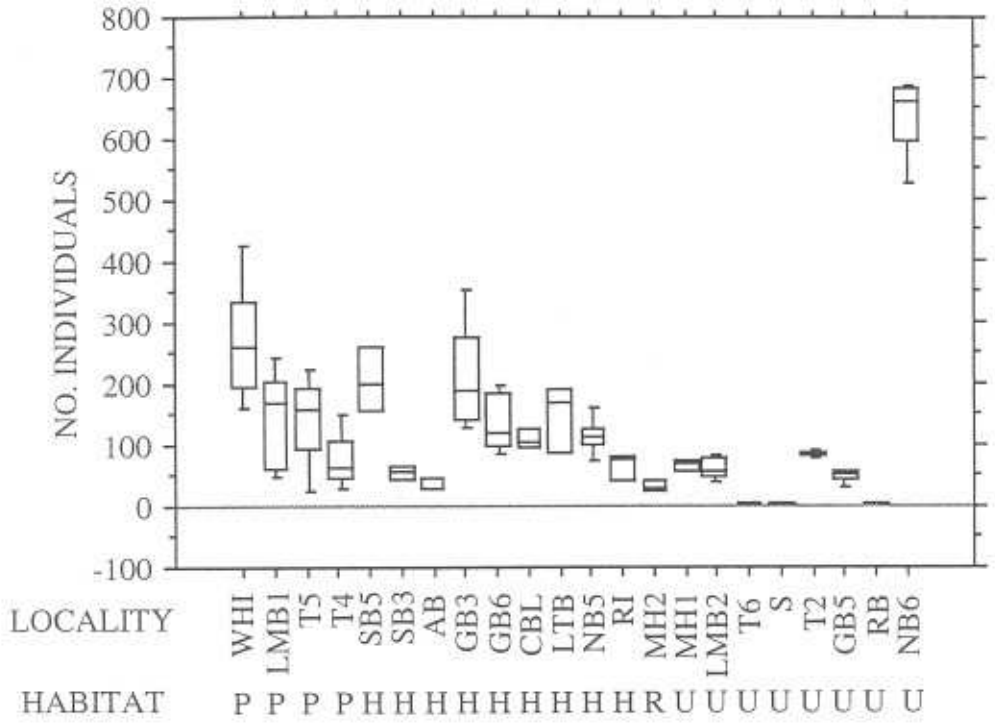


Fig. 2. Box plots for the number of individuals per core collected in the snapshot samples. P-(*Posidonia*); H-(*Heterozostera*); R-(*Ruppia*); U-(unvegetated)

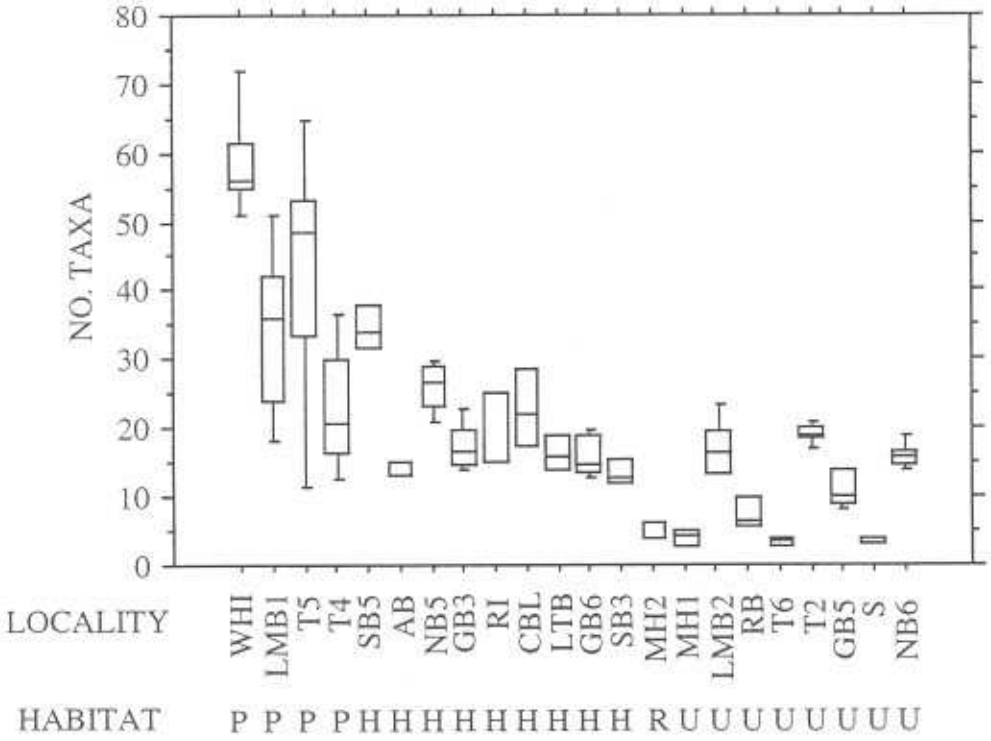


Fig. 3. Box plots for the number of taxa per core collected in the snapshot samples. P-(*Posidonia*); H-(*Heterozostera*); R-(*Ruppia*); U-(unvegetated)

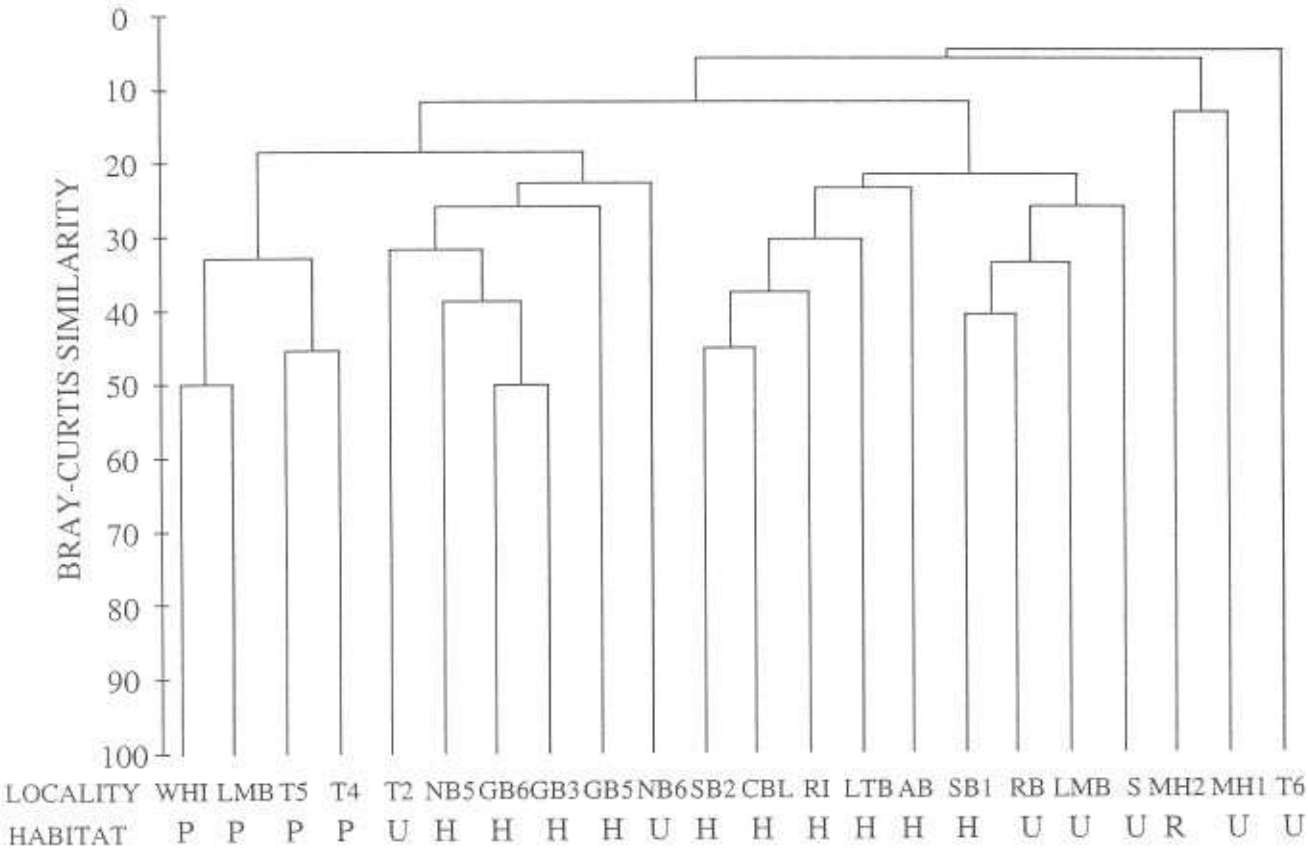


Fig. 4. Hierarchical agglomerative clustering of snapshot site data (double root transformed abundances) using group average linking. P-(*Posidonia*); H-(*Heterozostera*); R-(*Ruppia*); U-(unvegetated).

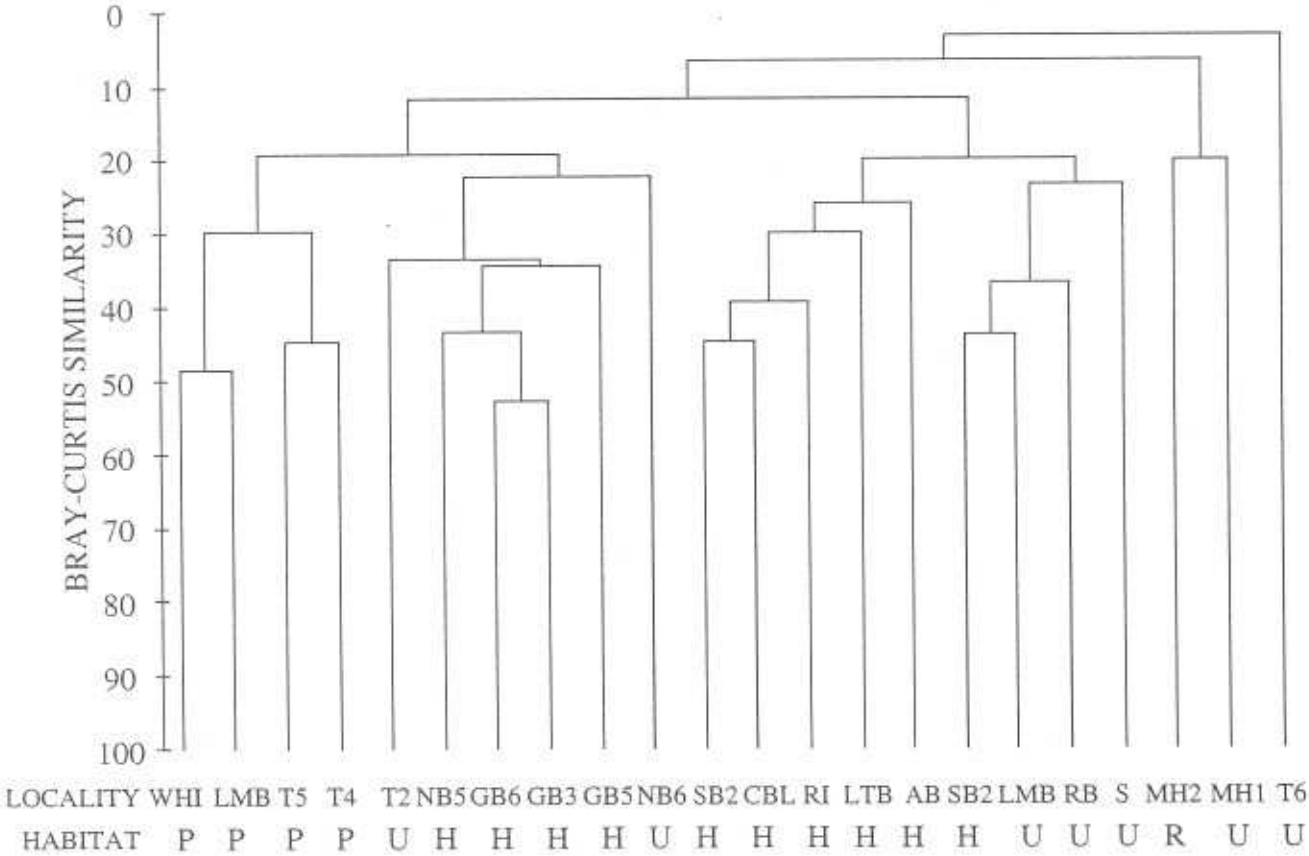


Fig. 5. Hierarchical agglomerative clustering of the snapshot site data (presence/absence) using group average linking. P-(*Posidonia*); H-(*Heterozostera*); R-(*Ruppia*); U-(unvegetated)

CHAPTER 5 - GENERAL DISCUSSION

The habitat study revealed little inherent difference in the abundance, diversity or species assemblages between the three coastal environment types surveyed. However, while most vegetated sites had higher abundance and diversity than unvegetated sites this was not true for all sites, particularly those in Norfolk Bay where there was little variation between habitat or depth strata. A distinct assemblage was apparent at the shallow sandy beach sites but a gradation of assemblage change occurred for all other sites. The structure of the invertebrate assemblages appear to be determined more by the site specific environmental conditions such as sediment and salinity than any habitat specificity, a pattern common to many soft-bottom invertebrate studies (Collett *et al.* 1984; Edgar 1990; Hutchings *et al.* 1991). Hence, in order to maximise invertebrate abundance, diversity and the range of invertebrate assemblages, a marine reserve system should encompass sandy beach habitats, and seagrass and mud habitats covering both shallow and deep strata over a broad range of environmental conditions.

No consistent temporal trend was apparent in invertebrate densities or diversity with different sites having maximum densities and diversity at different times of the year. The samples however provided further evidence that vegetated habitats do not have consistently higher abundance and diversity than unvegetated habitats. The invertebrate assemblages showed considerable temporal variability with autumn assemblages being markedly different at four out of nine sites. However, it is not known if the temporal shifts in relationships are truly seasonal or if they are simply the product of variability between different sets of samples.

This has implications when designing a study to identify representative habitats suitable for management as marine reserves as differences in interrelationships that sampling at different times of the year may reveal need to be investigated. Seasonal and within season sampling should be undertaken for at least one year to identify the effect of temporal variability in patterns of invertebrate assemblages.

In general, the snapshot survey revealed that most vegetated sites had higher densities and diversity than unvegetated sites with a trend for highest densities and diversity at marine dominated vegetated sites. However, not all marine vegetated sites possessed high densities. There was no trend apparent for the densities or diversity with regard to geographic location. The multivariate analysis indicates there is very little relationship between the species assemblages by habitat, or at both near and geographically separated sites. This supports the conclusions in Chapter 2 that in Tasmania, in order to cover the full range of inshore soft-bottom invertebrate assemblages marine reserves should encompass seagrass and unvegetated habitats covering a broad range of environmental conditions. However, in order to maximise invertebrate abundance and diversity this should be particularly targeted at marine dominated seagrass sites.

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